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Columbus West Interstate 90 final soils and geology report

COLUMBUS WEST

INTERSTATE 90
FINAL SOILS AND GEOLOGY REPORT

PREPARED FOR

HIGHWAY COMMISSION
STATE OF MONTANA

APRIL 1968

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FINAL SOILS AND GEOLOGY REPORT
COLUMBUS WEST
INTERSTATE 90
HIGHWAY COMMISSION
STATE OF MONTANA

I INTRODUCTION

This report contains recommendations for structural pavement sections, cut slopes, subdrainage, embankment and bridge foundations. There are suggested locations for common borrow and gravel aggregate pits. It is based on the exploratory work performed by the consultant and the State Highway Commission.

A Terrain

At the west end, the roadway begins at elevation 3710 in low bottom land of the Yellowstone River, running on embankment practically all the way to the Cardwell School bluff, Station 653. There will be a sidehill cut in the sandstone-shale layers of the bluff, Next, more terraces and flood plain as low as 3645 at Sta. 670 before the alignment enters the hills rising above the Yellowstone at about Sta. 750. It continues in the hills to a maximum Elev. of 3975 at Sta. 835 then drops out of the hills at Sta. 893. After leaving the hills, the alignment continues on embankment across irrigated farmland of the Keyser Creek drainage north of Columbus and terminates at Elev. 3660 at Sta. 937. The maximum change in elevation is 330 feet. Total length of alignment is about 9.3 miles.

B Procedure

Data from an extensive amount of work performed by the Montana State Highway Commission was utilized: logs from eleven core test holes in the hilly portion, eleven hand auger holes and numerous aggregate borrow test borings in the Yellowstone River meanders of the west portion. These, plus laboratory tests of aggregate and soil samples, are identified as to source where used in the report.

To start the new work, a geological reconnaissance was made of a two to three mile wide strip along the center of the alignment by the consultant. Sixty-six holes and fifteen pits were made by the consultant for roadway evaluation. Thirty-one holes were used to investigate five bridge sites. Twenty-two holes and six pits were needed to locate common borrow. A backhoe was used to dig pits to secure bulk samples. Five borings and seven pits were made to investigate a gravel aggregate source.

Samples were secured from holes and pits for tests in our laboratory. Tests included: mechanical analysis, Atterberg Limits, swell, consolidation, California Bearing Ratio, compaction, absorption and abrasion.

II GEOLOGY

A General

Hilly portions of this project are composed of nearly flat lying interbedded sandstones and shales of Cretaceous age. The regional dip of these beds is 5° to 7° north with a corresponding east-west strike. Formations exposed are identified as Hell Creek overlying Lennep. The upper portion of the latter formation is characterized by green-gray clay shale members. Outstanding members of the Hell Creek Formation are massive sandstone beds which are sufficiently erosion resistant to form bluffs.

The sandstones of the Lennep Formation have vertical joints intersecting at 80° to 90° and spaced at two to four feet.

Erosion surfaces of the formations in the hilly portion are lightly covered with one to two feet of sandy soils derived from nearby beds. In the lowland portions at east and west ends of this alignment formations are covered with soils ranging in depths up to fifty feet. The surface soils of the lowlands are mostly fine sands, silts and clays underlain by gravels within the meanders of the Yellowstone River.

There is little ground water present in the hilly portion of the alignment. Water was found in one boring and several small springs were located by reconnaissance. Ground water is shallow in most of the

lowland area and saturation to surface is common in areas lying downhill from irrigation ditches and irrigated fields. This alignment generally avoids swamps with only two small shallow ones near the west end.

A fault zone crosses the east end of the project, where there are two small fingers of the east-west trending Columbus regional fault. Vertical displacements up to 100 feet are reported on the down thrust side of the regional fault. Local residents living on the north edge of Columbus have experienced earthquake tremors of appreciable intensity.

B Climate

Precipitation at Columbus averages about thirteen inches per year, and the climate is typically semi-arid. Much of the rain falls in April, May and June. Numerous freezing and thawing cycles occur during the winter, which hold frost penetration to an estimated thirty-six inches maximum under highway pavements.

III SOILS AND ENGINEERING GEOLOGY

A Cuts

In general, bearings of cuts for this highway nearly parallel the strike of formation bedding. This factor provides for maximum stability of cut slopes. Slope angles are based on State criteria of 1:1 for cuts up to forty feet high and 1½:1 for cuts over forty feet high.

Rippability is enhanced by the vertical joint patterns of the sandstones. It is believed that the majority of the formation beds are rippable, exceptions are the massive sandstone members at Smith Coulee and Cardwell School, Stas. 730-737 and 648-658 respectively. Estimates are based on the use of the heaviest rippers available, otherwise additional blasting will be required in areas containing extensive thick sandstone beds. Characteristics of major cuts are dealt with below.

Embankments up to 150 feet high will be built in the hilly portion. Some high embankments will bear on side slopes containing expansive shales or on other isolated unfavorable bearing soils requiring special foundation treatment. Some drainages which contain springs will be blocked. Requirements for high embankment foundation treatment, and drainage are detailed below.

Expansive soils are found in a horizon intercepted on both the east and west slopes of the hilly portion. These include clay shales, weathered shales and clay soils derived from the shale. The alignment passes through the expansive horizon on the east approximately between elevation 3900 and 3820, Stas. 850 to 870. On the west side it is in the horizon from elevation 3700 to 3860, between Stas. 730 and 780. Locations and elevation reflect the regional formation dip.

Expansive soils are characterized by light green to gray color. Shales usually have a blocky structure with closely spaced joints, when dry the blocks are hard, when wet they have a greasy feel. Shales exposed to weather break down rapidly.

Specific locations of expansive soils are set forth in the Tabulation of Data. Catalytically blown asphalt membranes are recommended for stabilization, details for membrane application are set forth.

Cut Location: Sta. 648-658 WB; 649-657 EB

Site: Steep, rocky, timbered and brushy pasture with the Merrill Columbus irrigation ditch passing around the base of the hill. Light soil cover with large rocks.

Cut Slope: 1½:1

Cut Materials: Interbedded sandstones and shales with sandstones predominate. Massive sandstones are present but most sandstones are thin-bedded with shale partings. Beds dip gently to the north. Sandstones have vertical joints spaced at two to four feet intersecting at 80° to 90°.

Excavation: Considered to be 90% rippable, 10% blasting.

Cut Location: Sta. 727-737 WB

Site: Rocky pasture, some timber and brush with an old sandstone quarry.

Cut Slope: 1:1

Cut Materials: Thin-bedded sandstones with shale partings over massive sandstones underlain by shales. Beds dip gently to the north. Massive sandstones have vertical joints spaced at two to four feet intersecting at 80° to 90°.

Excavation: 30% rippable thin-bedded sandstones, 70% massive sandstone will require blasting.

Cut Location: Sta. 750-754 EB

Site: Steep rocky pasture with brush.

Cut Slope: 1:1

Cut Materials: Shales with thin sandstone beds. Beds nearly flat.

Excavation: 100% rippable.

Cut Location: Sta. 758-781 WB; 763-781 EB

Site: Steep south side of east-west ridge. Pasture with scant vegetation, occasional brush and trees. Light soil cover with sandstone and shale talus.

Cut Slope: 1½:1

Cut Materials: Interbedded sandstones and shales. Sandstones are thin-bedded and nearly flat-lying with a slight dip to the north.

Excavation: 100% rippable.

Cut Location: Sta. 783-797 WB; 782-799 EB

Site: Timbered and brushy hilly pasture, light soil cover.

Cut Slope: 1½:1

Cut Materials: Interbedded sandstones and shales. Sandstones are thin-bedded with a slight dip to the north.

Ground water was found at elevation 3970 and should be expected through the full length of these cuts.

Excavation: 100% rippable.

Cut Location: Sta. 813-834 WB; 811-823 EB

Site: Timbered and brushy hilly pasture, light soil cover.

Cut Slope: 1½:1

Cut Materials: Interbedded sandstones and shale. Sandstone beds to two feet thick. Beds dipping slightly to the north.

Excavation: Considered to be 100% rippable.

Cut Location: Sta. 826-841 EB

Site: Timbered and brushy hilly pasture. Light soil cover.

Cut Slope: 1½:1

Cut Materials: Interbedded sandstone and shales. Sandstone beds to two feet. Beds nearly flat-lying.

Excavation: Believed to be 100% rippable.

Cut Location: Stas. 856-874 WB; 854-864 EB

Site: Hilly pasture with light timber and brush, shallow soil cover.

Cut Slope: 1:1 EB; 1½:1 WB

Cut Materials: Shales with thin sandstone beds. Beds are nearly flat-lying.

Excavation: 100% rippable.

Cut Location: Sta. 876-881 EB

Site: Hilly pasture with some timber and brush. Light soil cover.

Cut Slope: 1:1

Cut Materials: Interbedded sandstones to shale. Sandstone beds to two feet thick. Beds are nearly flat-lying.

Excavation: 100% rippable.

Cut Location: Sta. 918-922

Site: A barren hill

Cut Slope: 1:1

Cut Materials: Sandy shales.

Excavation: 100% rippable.

B Drainage

There are several areas on the flood plain or terraces of the Yellowstone River where embankments will settle. These are small shallow swamps, and wet spots where seepage from adjacent irrigation canals has softened non-organic silty soils.

In the hilly portion embankments will block natural drainages, some contain springs. One cut will intercept ground water. Perforated subdrains and culverts are needed to prevent saturation of subgrade and embankment soils.

1. Swamps

Location: Sta. 553-559; 565-567 EB and WB

Depth: One to two feet of organic muck underlain by gravel. shallow water table.

Recommendation: Remove muck and backfill with gravel or sandstone fragments. Surcharging not required.

2. Surcharges

Location: Sta. 538-542; 580-586; 635-648; 658-675 All EB and WB

Seepage from the canal at these locations has produced a shallow perched water table and softened the soil from its original desiccated state to semi-saturated, and moderately compressible. Depth of softened soil varies from 8-15 feet, it is underlain by gravel or firm shale. Estimated settlement ranges from six inches to one foot within the first and fourth station interval listed above and six inches for the second and third intervals because embankments are lower. Safety factor with respect to shear failure of embankment plus surcharge is at least 2.

Recommendation: Place five foot surcharge on each interval listed above, and allow it to remain throughout the winter or for at least three months.

3. Perforated Subdrain

Location: Sta. 767-782 EB; 781 WB

Intermittent stream drainages with springs downhill at Sta. 779 and 781 EB will be blocked by embankments.

Recommendation: Perforated subdrain right side of EB Sta. 767 to 782. Culverts beneath both embankments Sta. 781 WB and Sta. 782 EB, draining to west.

Location: Sta. 781-799 EB; 782-792 WB

Deep cuts in hilltop formations will intercept ground water.

Recommendation: Perforated subdrains, left sides of westbound and eastbound for their full length.

Location: Sta. 862-888 Median EB and WB

Intermittent stream drainage with evidence of old spring in median at Sta. 876. Drainage will parallel cuts, embankments will block drainage.

Recommendation: Perforated subdrain right side of WB Sta. 875 to divert towards east.

Location: Sta. 901-912 EB

Seepage from irrigation canal adjacent to the roadway is moving towards a natural drainage.

Recommendation: Perforated subdrain on the right side of the eastbound lane to intercept seepage.

4. Culverts

Location: Sta. 744 EB and WB

Intermittent stream drainage intersected at right angles will be blocked by embankment.

Recommendation: Culvert beneath both embankments, drain to the south.

Location: Sta. 805 EB; 804 WB

Intermittent stream drainage with spring at Sta. 805, intersected at right angles, embankments will block drainage.

Recommendation: Culverts beneath both embankments to drain south.

Location: Sta. 856 EB; 857 WB

Intermittent stream drainage intersected at right angles, embankments will block drainage.

Recommendation: Culverts beneath both embankments to drain north.

Location: 891 EB

Intermittent stream drainage intersected at right angle, embankment will block drainage.

Recommendation: Culvert beneath eastbound lane at Sta. 891+50, to drain south.

5. Ditch Lining

Locations: Sta. 538+50-543; 582-587; 612-626; 641-674

Recommendation: Ditch relocations at these intervals must be lined. Ditch section passes from a channel cut into bedrock to new embankment at several points, lining should be able to tolerate differential settlements of several inches caused by settlement of the new embankment after saturation.

6. Membrane

Expansive soils will comprise portions of the subgrade in certain cut areas. These areas are dealt with individually in the "Tabulation of Data." Catalytically blown hot asphalt membranes are recommended to prevent intrusion of moisture from the base into the subgrade and keep expansive soils in equilibrium.1/ Membranes are not recommended where a water table is present. Recommended application rate is 1.3 gallons per square yard, yielding a membrane about 3/16" thick. One to two inches of A-2(10) sand, 100% passing #10 sieve, should be laid on the membrane to protect it against damage during placement of aggregate base. Sand cushion can be considered a part of the total structural thickness. Membrane should extend unbroken from points on right

---

1/ Ref. 1 "Use of Asphalt Membranes to Reduce Expansion in Certain Types of Expansive Soils" by Bud A. Brakey, presented at 1968 Highway Engineers Conference, University of Colorado.

and left cut slope three feet above the ditch line and across the entire roadway to obtain maximum benefit. Membrane in ditches should be protected by six inches of soil cover.

To achieve similar although not as certain results at lower cost the membrane can be stopped three feet short of the ditch lines on the 6:1 shoulder slopes. It would not extend under the ditch nor up the backslope eliminating the need for subexcavating six inches in the ditch and replacing earth for protection.

At least one day prior to membrane application, subgrade surface irregularities should be eliminated by a flat wheeled roller and a light application of diluted SS-1 emulsion should be made to prevent foaming when the membrane is applied. Emulsion should yield a residual asphalt coating of 0.03 to 0.05 gallons per square yard. Application temperature of the membrane asphalt should range from 350° F to 400° F. Thin areas should be eliminated by hand spray work.

SPECIFICATIONS FOR CATALYTICALLY BLOWN ASPHALT

Asphalt used as a membrane shall be 50-60 penetration grade, and shall be prepared by catalytic blowing petroleum asphalt. The use of iron chlorides or compounds thereof will not be permitted. Asphalt shall be homogeneous, free of water and shall not foam when heated to 347° F. It shall meet the following specific requirements.

Test Designation	Test Method ASTM	50-60 Penetration Grade
Flash Point	D 92	425° F. Min.
Softening Point	D 36	175° F. - 225° F.
Penetration, 77° F., 100 gms., 5 Sec.	D 5	50-60
Penetration, 32° F., 200 gms.,60 Sec.	D 5	30 Min.
Penetration, 115° F., 50 gms., 5 Sec.	D 5	120 Max.
Ductility, 77° F. (5cm per min) cm	D 113	3.5 Min.
Loss on Heating, 325° F. in 5 hrs.	D 6	1.0 Max.
Penetration of residue, 77° F. (100 gms., 5 sec. compared to original) %		60.0 Min.
Solubility in CCl_4, %	D 165	97.0 Min.

C High Embankments

Special foundations are recommended for portions of embankments bearing on unfavorable downslope soils. A bonded rockfill toe is specified in the following tabulation of individual embankments.

Bonded rockfills should be constructed as follows:

a- Remove overburden soils and weathered shales from rockfill toe bearing area.

b- Machine dump and place open-graded fragmented rock having a maximum size of twelve inches.

c- Completed bonded rockfill should be a minimum of ten feet wide and three feet deep.

Location: Sta. 741-758 WB; 735-749 EB

Max. Height: 64' WB; 48' EB

Site: Intermittent stream drainage crossed at right angle. Westbound fill extends on to north slope of hill.

Foundation Soils: Silts and gravelly silts in drainage, interbedded sandstones and expansive shales on hillside.

Recommendation: Bonded rockfill toe, westbound on hillside Sta. 750 to 758, eastbound Sta. 735 to 749.

Location: Sta. 754-773 EB

Max. Height: 34'

Site: Steep south slope of ridge paralleling the alignment.

Foundation Soils: Interbedded sandstones and expansive shales.

Recommendation: Bonded rockfill toe Sta. 754-773 EB

Location: Sta. 797-812 WB; 799-810 EB

Max. Height: 155' WB; 150' EB

Site: Steep intermittent stream drainage to be crossed at right angle. Drainage contains a spring.

Foundation Soils: Shallow silts in bottom of drainage, interbedded sandstones and shales on slopes of drainage.

Recommendation: Rockfill toe of eastbound across drainage Sta. 803 to 805. Westbound abuts hillside. Culvert is specified for drainage.

Location: Sta. 834-847 WB

Max. Height: 60'

Site: Steep intermittent stream drainage parallel and then turns and crosses at Sta. 843

Foundation Soils: Shallow silts over interbedded sandstones and shales.

Recommendations: No special foundation requirement. Perforated subdrains are specified.

Location: Sta. 847-859 WB, 847-854 EB

Max. Height: 60' WB; 80' EB

Site: Westbound parallels north slope then crosses sharp drainage at right angle. Eastbound crosses drainage at right angle.

Foundation Soils: Shallow silts over interbedded sandstones and expansive shales.

Recommendation: Bonded rockfill toe, westbound left side Sta. 847 to 853 and 855 to 857; eastbound left side Sta. 847 to 850.

IV PAVEMENT DESIGN

A General

Several variables have been considered in establishing structural pavement thicknesses: soil classification in the several reaches of subgrade,representative California Bearing Ratios, frost penetration, and projected daily traffic. Structural thickness was selected from charts contained in the "Interim Guide."

B Subgrade

After a study of soil profiles and the mass diagram the project was divided into nine sections of similar subgrade. Predominant materials in each cut, soil at subgrade level, and the combined structural sections are shown on the "Tabulation of Data" station by station. Locations where asphalt membrane is to be sprayed on expansive subgrade are called out.

Frost penetration in the vicinity of Columbus is three feet, all of the soils from the roadway cuts and borrow sources are frost susceptible, the only exception is fragmented sandstone. Consequently frost, not shear strength, controls the design wherever the subgrade California Bearing Ratio is greater than 5. Normal engineering practice is to provide a thickness of non-frost susceptible material equal to one-half the depth of frost penetration. In this case it

is three feet, thus the minimum structural thickness is 1.5 feet regardless of the CBR.

The Kentucky CBR Column C on the AASHO Interim Guide "Correlation Chart for Estimating Soil Support (S)" was used. The CBR procedure is given on page E-2 of the "Interim Guide," it consists of molding a soil specimen near optimum moisture content with ten blows of a ten pound hammer dropped eighteen inches on each of five equal layers. Specimen is soaked for four days before penetration with the Standard CBR piston. Load-penetration curves are attached. Representative CBR values and corresponding soil support values are:

	Design CBR	Soil Support S	SN
Silty or clayey overburden	2.0	3	4.2
Swelling shale	2.0	3	4.2
Non-expansive shale	7	5.2	3.2*
Fragmented sandstone	15	6.8	2.4*
Berry Creek Borrow	15	6.8	2.4*

* Frost Controls Design

C Traffic

Projected Interstate 90 traffic for 1991 (ADT) is 5700, traffic count for 1965 was 1746, average daily traffic is 3720±. The

Department assumes that truck traffic amounts to 12%, therefore the average daily truck traffic is 450, or 225 trucks each way. According to Loadometer data collected throughout the state of Montana, there are 323.3 equivalent 18 kip single axle loads per 1000 trucks. Equivalent daily 18 kip load applications on this project:

$\frac{225}{1000} \times 323.3 = 72.5$ say 75 repetitions of an 18 kip load per day

Entering the "Interim Guide" design chart for flexible pavements with a serviceability index of 2.5, a 2.5 regional factor, seventy-five 18 kip repetitions and the various soil support values, we determined the weighted structural number shown in the last column above. (SN) Asphalt concrete pavement plus Grade 5 base totaling 1.05 feet already established for Columbus East Interchange should be continued on through the Columbus West project making adjustments in thickness of Grade 2 subbase to attain the required structural number for each subgrade type.

D Selective Grading

Pavement thickness over fragmented sandstone subgrades, which are non-frost susceptible, could be less than half the frost penetration depth if grading was done selectively, thus Grade 2 subbase could be eliminated entirely over sandstone subgrade. Alternate designs were

prepared, one with selective grading during construction to insure that the best available subgrade materials are used at the top of embankments together with short stretches of undercutting. The second design is based on ordinary grading practice with no special attempt to insure that superior subgrade materials are placed at the top of embankments and with no undercutting. After allowing for undercutting, rehandling and stockpiling, it is estimated that the saving using selective grading would be about $30,000 for the project. This is considered an insignificant percentage of the total cost, therefore in view of on-the-job complications connected with selective grading the design without selective grading is recommended.

E Structural Sections

The following pavement sections are recommended:

	Thickness		SN
	0.35'	Plant Mix Bit. Surf. Type 3	1.68
	0.20'	Top Surf. Type A leveling	0.34
	0.50'	Crushed Base Type A Grade 5	0.84
+	1.00'	Crushed Base Type A Grade 2	1.44
Total	2.05'	CBR of 2 = S of 3	4.30
		SN required = 4.2	

	0.35'	Plant Mix Bit. Surf. Type 3	1.68
	0.20'	Top Surf. Type A leveling	0.34
	0.50'	Crushed Base Type A Grade 5	0.84
+	0.50'	Crushed Base Type A Grade 2	0.70
Total	1.55'	CBR of 7 = S of 5.2	3.56*
		SN required = 3.2*	

* Frost Controls Design

F Local Roads

Craver Road runs under the Interstate about at existing grade, its subgrade is primarily silt, the California Bearing Ratio is 2 and soil support value is 3. Rapelje is another local road and it crosses the Interstate on an embankment. Practically all of the borrow materials in the vicinity of Rapelje are clays and shales with a support value of 3. Paved portions of both roads within construction limits have the following structural sections:

Thickness		SN
0.20'	Plant Mix Bit. Surf. Type 3	0.96
0.20'	Top Surf. Type A leveling	0.34
0.60'	Crushed Base Type A Grade 5	1.00
1.00'	Total	2.30

Predicted traffic at Rapelje is 160 vehicles per day both directions, or 80 each way. 12% truck traffic is 10 trucks, equivalent to roughly 3 repetitions of an 18 kip load. Traffic at Craver Road is substantially less. By extrapolation from the "Interim Guide" the structural number required is about 2.3.

It is doubtful if the "Interim Guide" can be applied to a gravel surfaced road, however according to the Highway Research Board Group Index design chart the gravel surfaced sections one foot thick are adequate for "medium traffic," defined as 50-300 commercial vehicles per day.

G

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS
Tabulation of Data

Stations Eastbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
445+76 to 518+33	Existing Highway				
	Silty Clay A-4	Silty Clay	.95	No	2.05
523+00					
	Embankment from Berry Creek			No	1.55
556+00					
	At Grade Silty clay		.95	No	2.05
568+00					
	Embankment from Berry Creek			No	1.55
586+25					
	Silty Clay A-4	Silty Clay	.95	No	2.05
589+00					
	Embankment			No	1.55
615+00					
	Short cuts Silty clay	Silty Clay	.95	No	2.05
622+00					
	Embankment			No	2.05
648+70					
	Sandstones, shales and silty clays	Sandstone, expansive shales and silty clay	1.00	Yes	2.05
657+25					
	Embankment			No	2.05
750+00					

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS

Stations Eastbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
750+00					
	Sandstones and shales	Sandstone and expansive shales	1.10	Yes	2.05
753+70					
	Embankment			No	2.05
762+50					
	Sandstones and shales	Sandstone and expansive shale	1.10	Yes	2.05
781+40					
	Sandstones and sandy shale	Sandstone and sandy shales Subdrain 781-799	1.15	No	1.55
798+70					
	Embankment			No	1.55
810+60					
	Sandstone and sandy shales	Sandstone and shales	1.15	Yes	1.55
823+20					
	Embankment			No	1.55
826+10					
	Sandstone and sandy shales	Sandstone and sandy shales	1.15	Yes	1.55
843+20					
	Embankment			No	1.55
845+40					
	Sandstone and sandy shales	Sandstone and sandy shales	1.15	No	1.55
846+80					
	Embankment			No	1.55
854+30					
	Sandstone and expansive shales	Sandstone and expansive shales	1.10	Yes	2.05
866+40					

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS

Stations Eastbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
866+40					
	Embankment			No	2.05
872+70					
	Sandstone and expansive shale	Sandstone and expansive shale	1.10	Yes	2.05
873+00					
	Embankment			No	2.05
876+00					
	Sandstone and expansive shale	Sandstone and expansive shale	1.10	Yes	2.05
880+80					
	Embankment			No	2.05
884+90					
	Sandstone and expansive shale	Sandstone and expansive shale	1.10	Yes	2.05
891+20					
	Embankment			No	2.05
891+70					
	Sandstone and expansive shale	Sandstone and expansive shale	1.10	Yes	2.05
902+50					
	Embankment			No	2.05
918+10					
	Sandy shales and silt	Sandy shale and silt	1.00	No	2.05
921+50					
	Embankment			No	2.05
924+40					
	Silty clay	Silty Clay	.95	No	2.05
926+00					
	Embankment			No	2.05
927+85					

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS

Station Westbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
445+76					
	Embankment			No	2.05
454+25					
	Silty Clay A-4	Silty Clay	.95	No	2.05
462+25					
	Underpass Structure				
463+75					
	Silty Clay A-4	Silty Clay	.95	No	2.05
523+00					
	Embankment from Berry Creek	Swamp 553-559 Overexcavate Seepage 538-542 Surcharge		No	1.55
556+00					
	At Grade Silty Clay	Swamp 565-567 Overexcavate	.95	No	2.05
568+00					
	Embankment from Berry Creek	Seepage 580-586 Surcharge		No	1.55
586+25					
	Silty Clay A-4	Silty Clay	.95	No	2.05
589+00					
	Embankment			No	1.55
615+00					
	Short Silty clay cuts	Silty Clay	.95	No	2.05
622+00					
	Embankment	Seepage 635-648 Surcharge		No	2.05
648+00					

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS

Station Westbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
648+00					
	Sandstones and shales	Sandstones and expansive shales	1.10	Yes	2.05
657+25					
	Embankment	Seepage 658-675 Surcharge		No	2.05
727+25					
	Sandstones and shales	Sandstones and expansive shale	1.10	Yes	2.05
737+30					
	Embankment			No	2.05
758+00					
	Sandstones and shales	Sandstones and expansive shales Spring at 780 90 feet below grade	1.10	Yes	2.05
781+00					
	Embankment				2.05
783+40					
	Sandstones and shales	Sandstones and sandy shales with water at Elev. 3970 Subdrain 782-792	1.15	No	1.55
796+50					
	Embankment	Spring at 805 150' below grade		No	1.55
812+50					
	Sandstones and shales	Sandstones and shales	1.15	Yes	1.55
833+65					
	Embankment	Spring at 835 30' below grade		No	1.55
855+90					
	Sandstones and shales	Sandstones and expansive shales	1.10	Yes	2.05
874+35					
	Embankment	Spring at 876 in median 20' below grade		No	2.05
879+00					

COLUMBUS WEST I-90
PAVEMENT DESIGN SECTIONS

Station Westbound	Cut Material	Subgrade	Excav. Factor	Membrane Req'd.	Structural Thickness Ft.
879+00					
	Sandy silt	Sandy Silt	.95	No	2.05
880+15					
	Embankment			No	2.05
892+40					
	Silts and weathered shales	Expansive shales and silts	1.00	Yes	2.05
902+00					
	Embankment			No	2.05
918+20					
	Sandy shale and silt	Silt and shale	1.00	No	2.05
922+00					
	Embankment			No	2.05
924+70					
	Silty Clay	Silty Clay	.95	No	2.05
928+03					

BORROW SOURCE No. 1

Location: Berry Creek Drainage in Sections 33 and 28, T1S, R19E.

Site: Non-irrigated pasture and hay meadow 0.2 to 0.8 miles north of the right-of-way, Pierce Ranch property. Partially visible from Interstate.

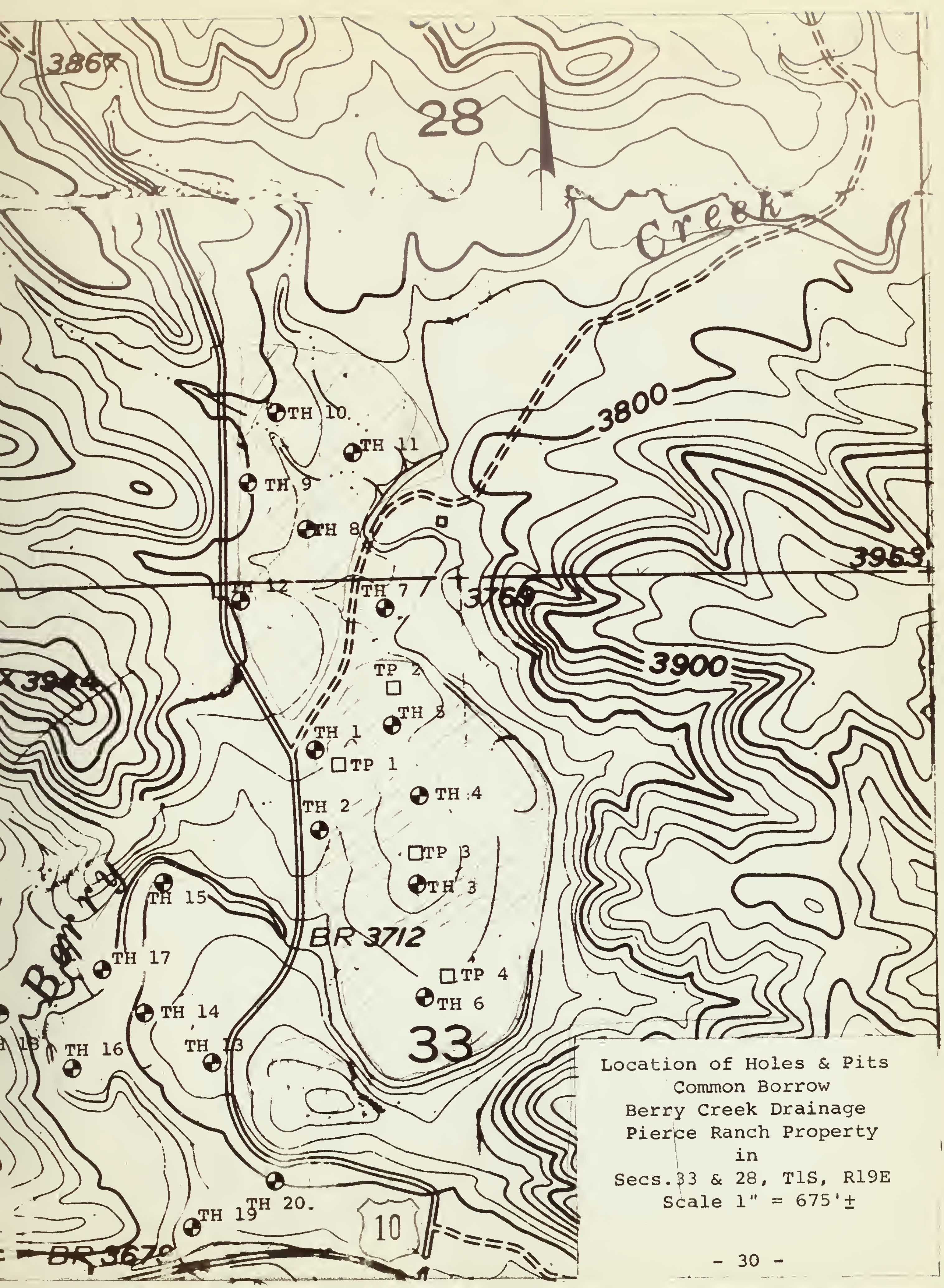
Access: By existing county road (Craver Road) which passes along the edges of the areas and terminates at Craver Interchange to the south. Haul to Interstate 0.2-0.8 miles to Sta. 534.

Quantities:	Pasture lands . . .	1 million cu. yds.
	Hay meadows . . .	½ million cu. yds.

Nature of Deposit: Silty sands and gravels maximum size 6 inches overlying weathered sandstones and shales. The depth of overburden ranges up to 1.5 feet. Can be readily excavated to an average depth of ten feet, an additional 3-5 feet can be taken by ripping the weathered sandstones. Ground water below fifteen feet.

CBR Values:	Silty sands and gravels	15
	Weathered sandstones	15

Recommendations: The Berry Creek Pit is preferred to the Stump Gulch Pit because its upper reaches are not visible from the Interstate and the quantity of borrow available is much greater.

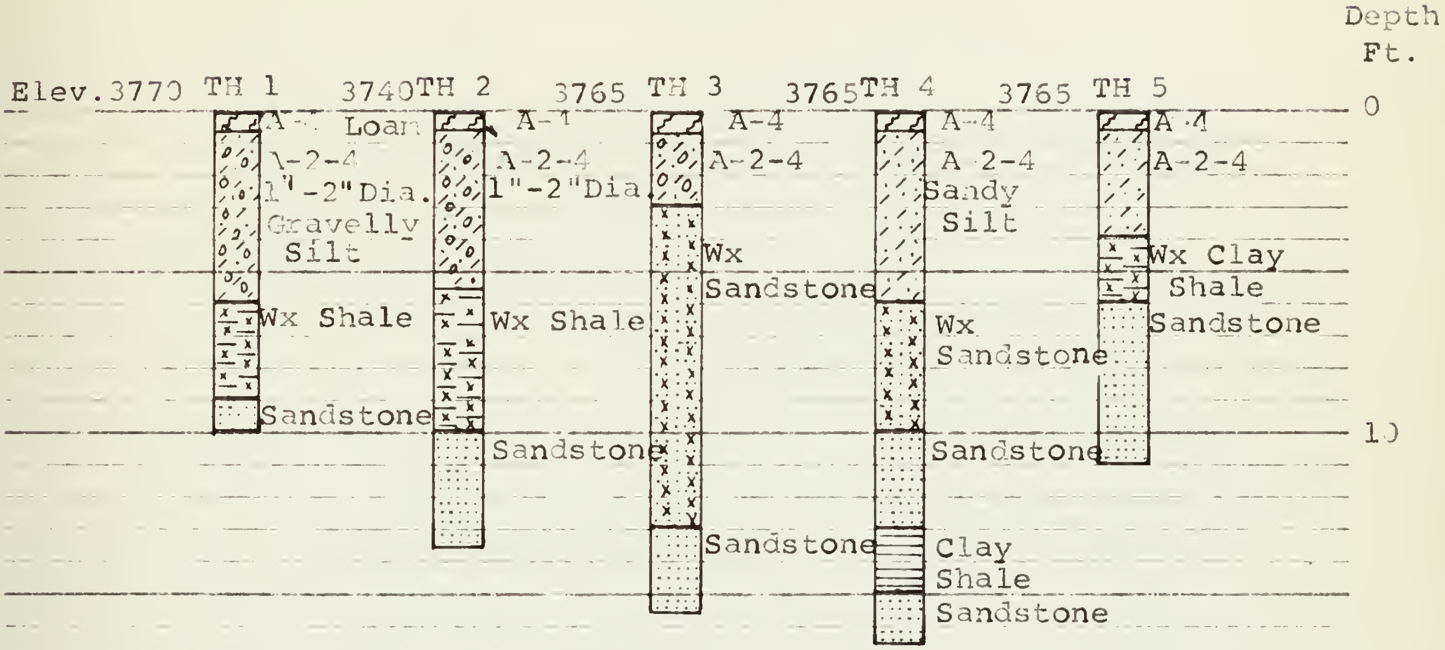


Location of Holes & Pits
Common Borrow
Berry Creek Drainage
Pierce Ranch Property
in
Secs. 33 & 28, T1S, R19E
Scale 1" = 675' ±

PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

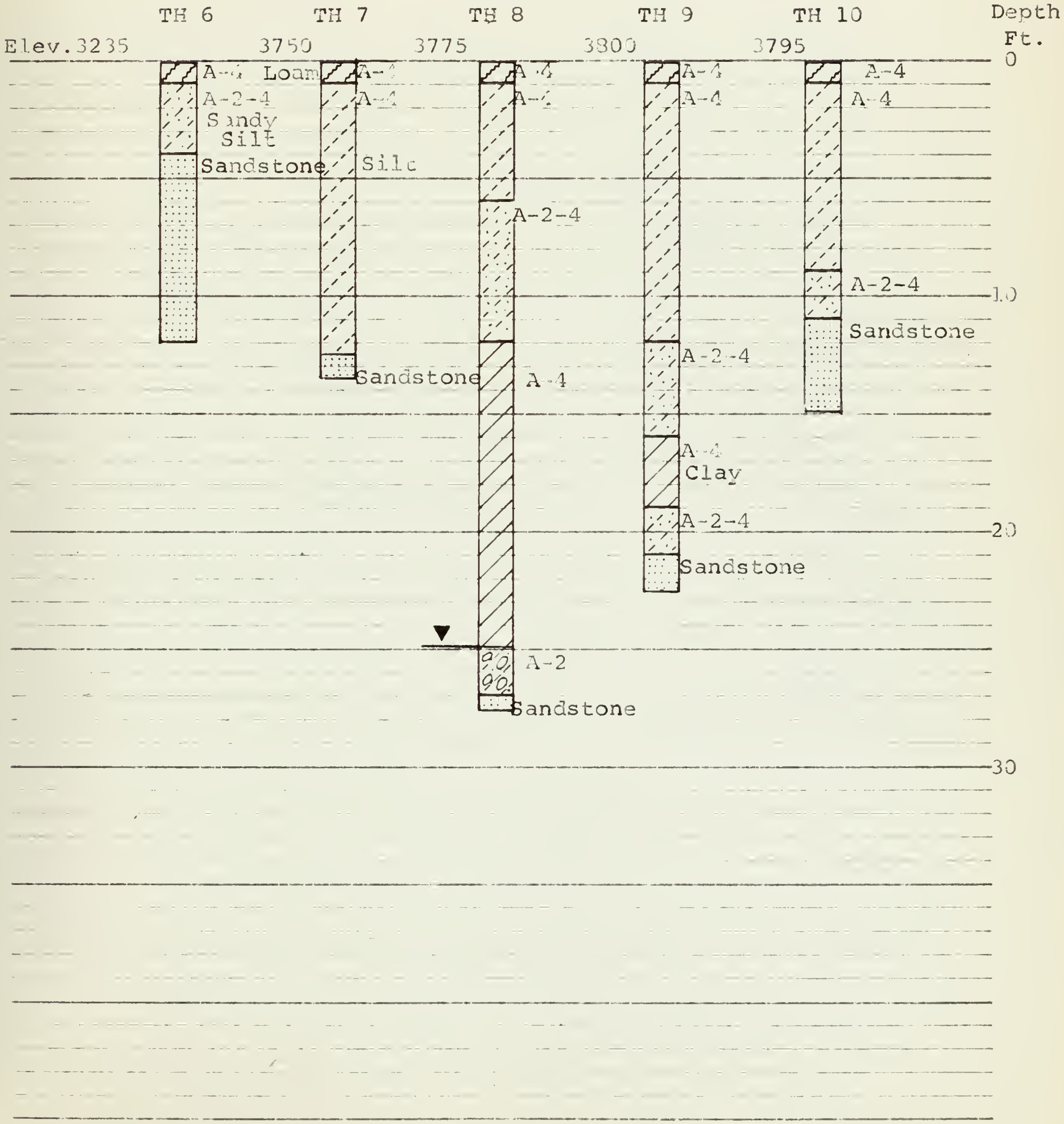
Berry Creek Borrow
Test Holes



PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

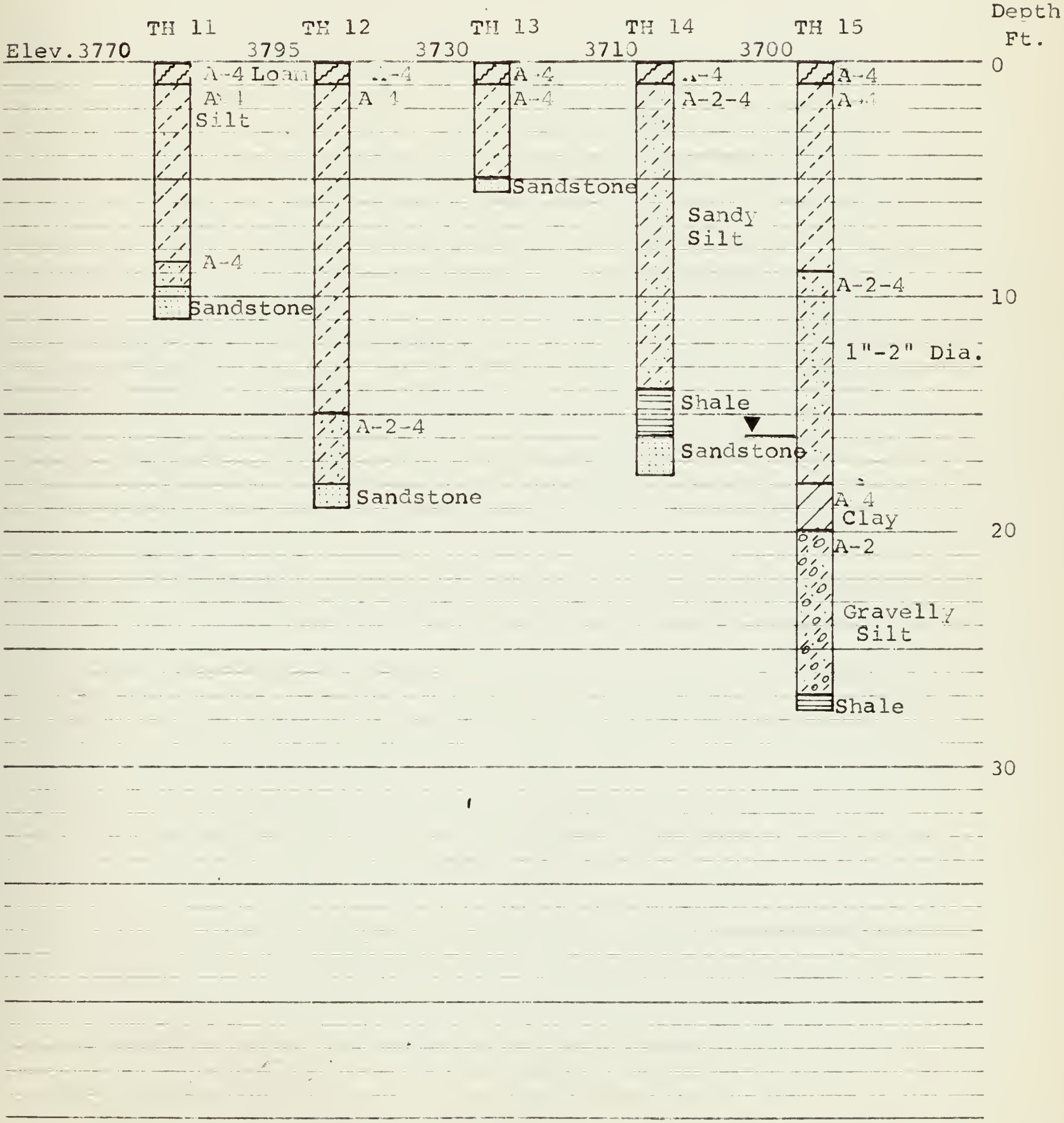
Berry Creek Borrow
Test Holes



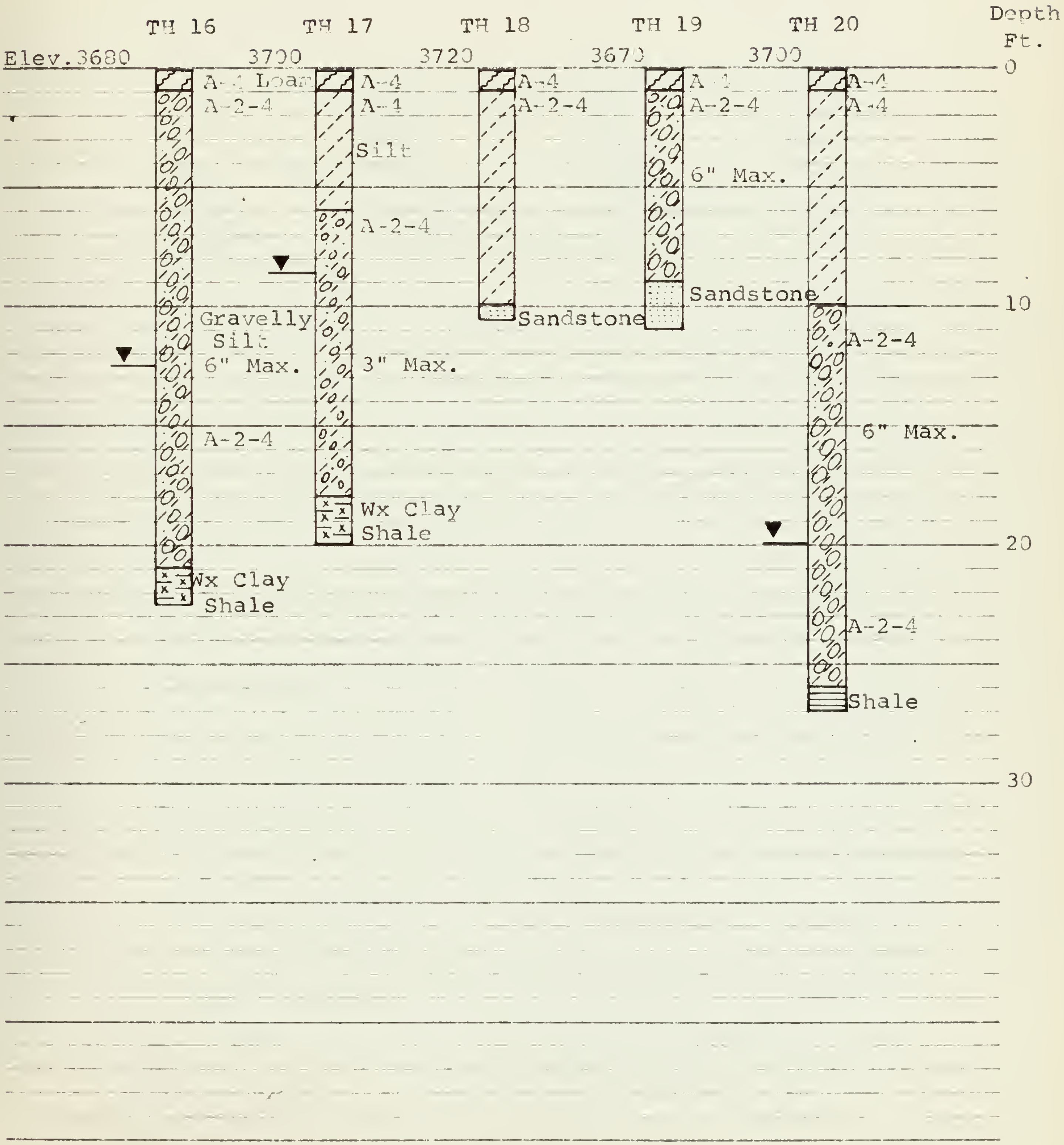
PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Berry Creek Borrow
Test Holes



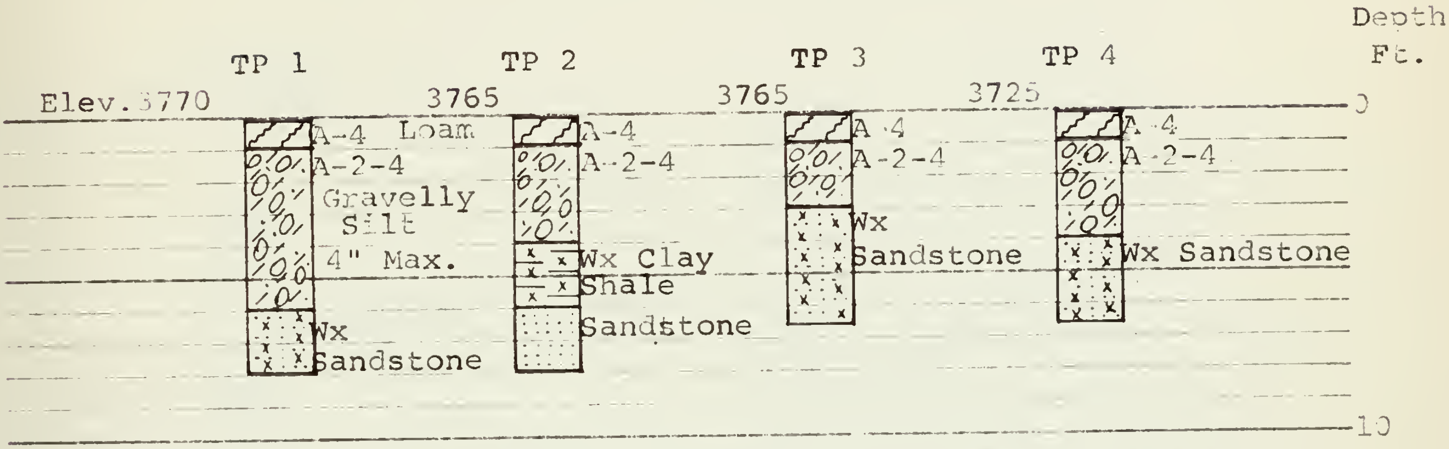
Berry Creek Borrow
Test Holes



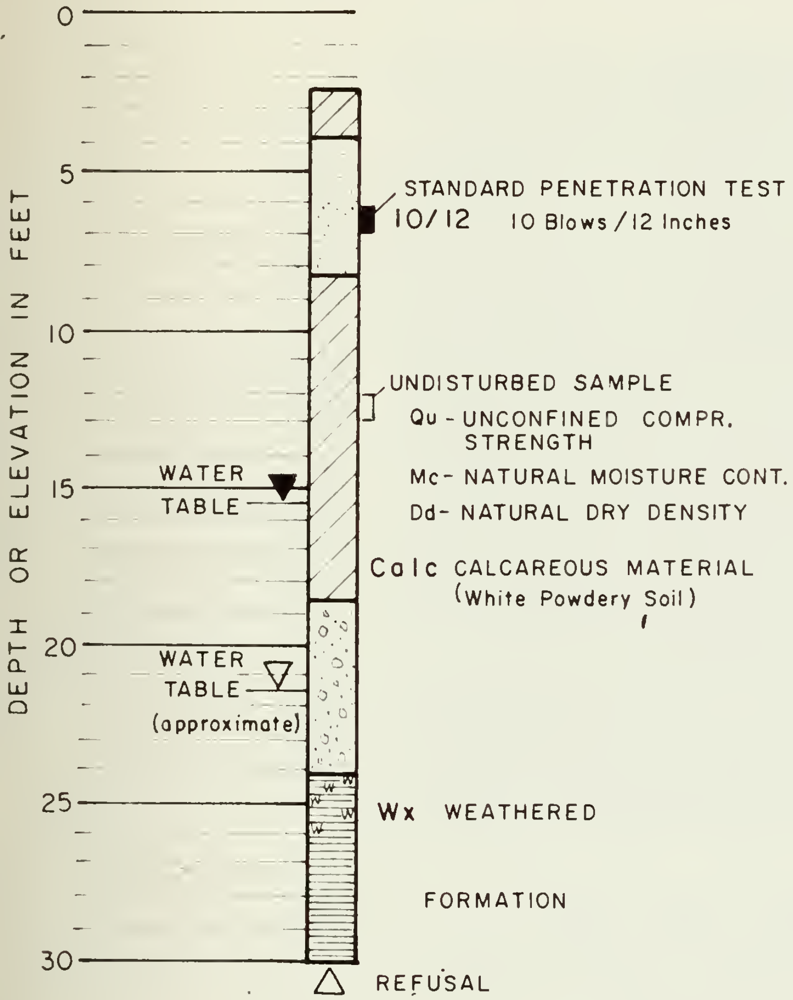
PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Berry Creek Borrow Pits



TYPICAL TEST HOLE LOG


DEPTH OR ELEVATION IN FEET
0
5
10
15
20
25
30
STANDARD PENETRATION TEST
10/12 10 Blows / 12 Inches
UNDISTURBED SAMPLE
Qu - UNCONFINED COMPR. STRENGTH
Mc - NATURAL MOISTURE CONT.
Dd - NATURAL DRY DENSITY
Calc CALCAREOUS MATERIAL (White Powdery Soil)
WATER TABLE
WATER TABLE (approximate)
Wx WEATHERED
FORMATION
REFUSAL

SYMBOLS

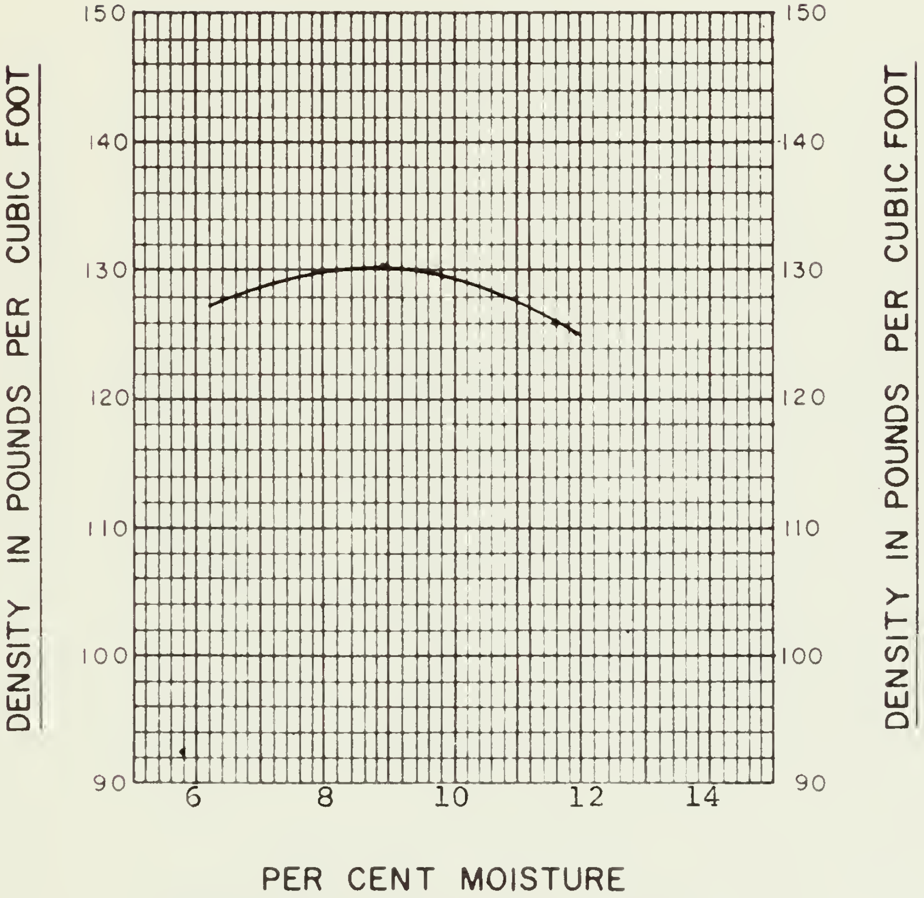
SYMBOL		DESCRIPTION - AASHO
░	A-1-a	WELL-GRADED CLEAN GRAVELS
░	A-1-b	POORLY GRADED CLEAN GRAVELS
▨	A-1-b A-2-4	GRAVEL-SAND-SILT MIXTURES
▨	A-1-b A-2-6	GRAVEL-SAND-CLAY MIXTURES
░	A-1-b	WELL GRADED SANDS
░	A-2-4 A-3	POORLY GRADED CLEAN SANDS
▨	A-2-4 A-4	SAND-SILT MIXTURES
▨	A-2-6 A-6	SAND CLAY MIXTURES
▨	A-4	SILTS OR SILTY SAND
▨	A-6	LEAN CLAYS
░	A-7-5 A-5	ELASTIC SILTS
▨	A-7-6	FAT CLAYS
▨		ORGANIC SILTS OR CLAYS
✓		PEAT OR COAL

FORMATION SYMBOLS

▤	CLAY SHALE
░	SANDSTONE
▤	SILTSTONE
▦	BEDROCK

KEY TO BORING LOGS

(NOT AN ACTUAL LOG)

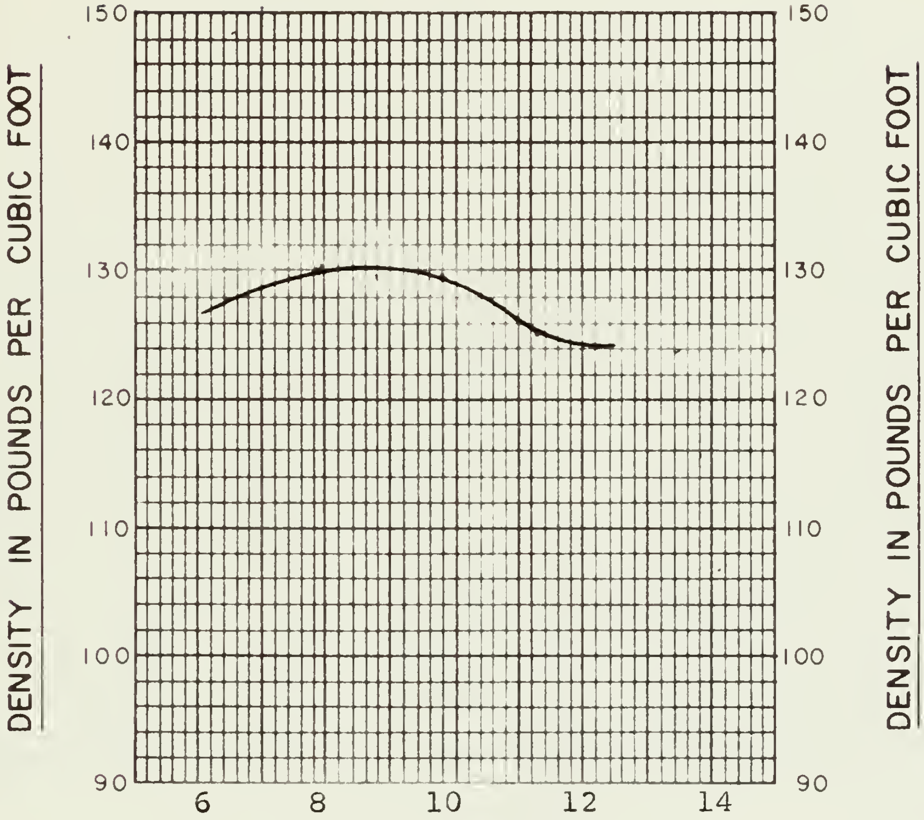


Berry Creek Borrow Pit #1 @ 1'- 6'
Sample # 6

MOISTURE — DENSITY CURVE

TEST METHOD	T-99-D
OPTIMUM MOISTURE	8.5%
MAXIMUM DRY DENSITY	130.5 PCF

Liquid Limit	16
Plasticity Index	NP
#4	79
#200	26

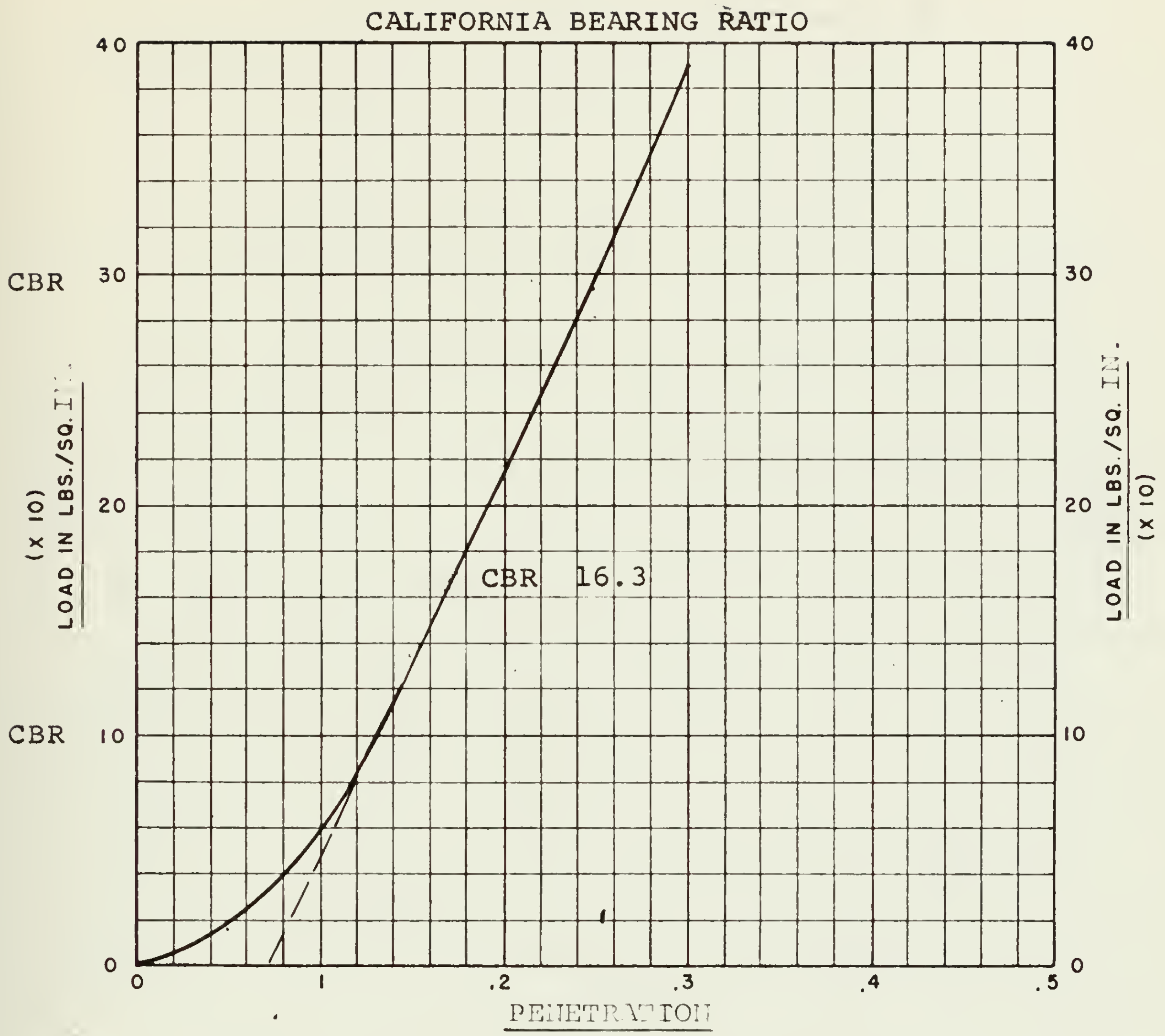


PER CENT MOISTURE
Berry Creek Borrow Pit #4 @ 4'- 6'
Sample #8

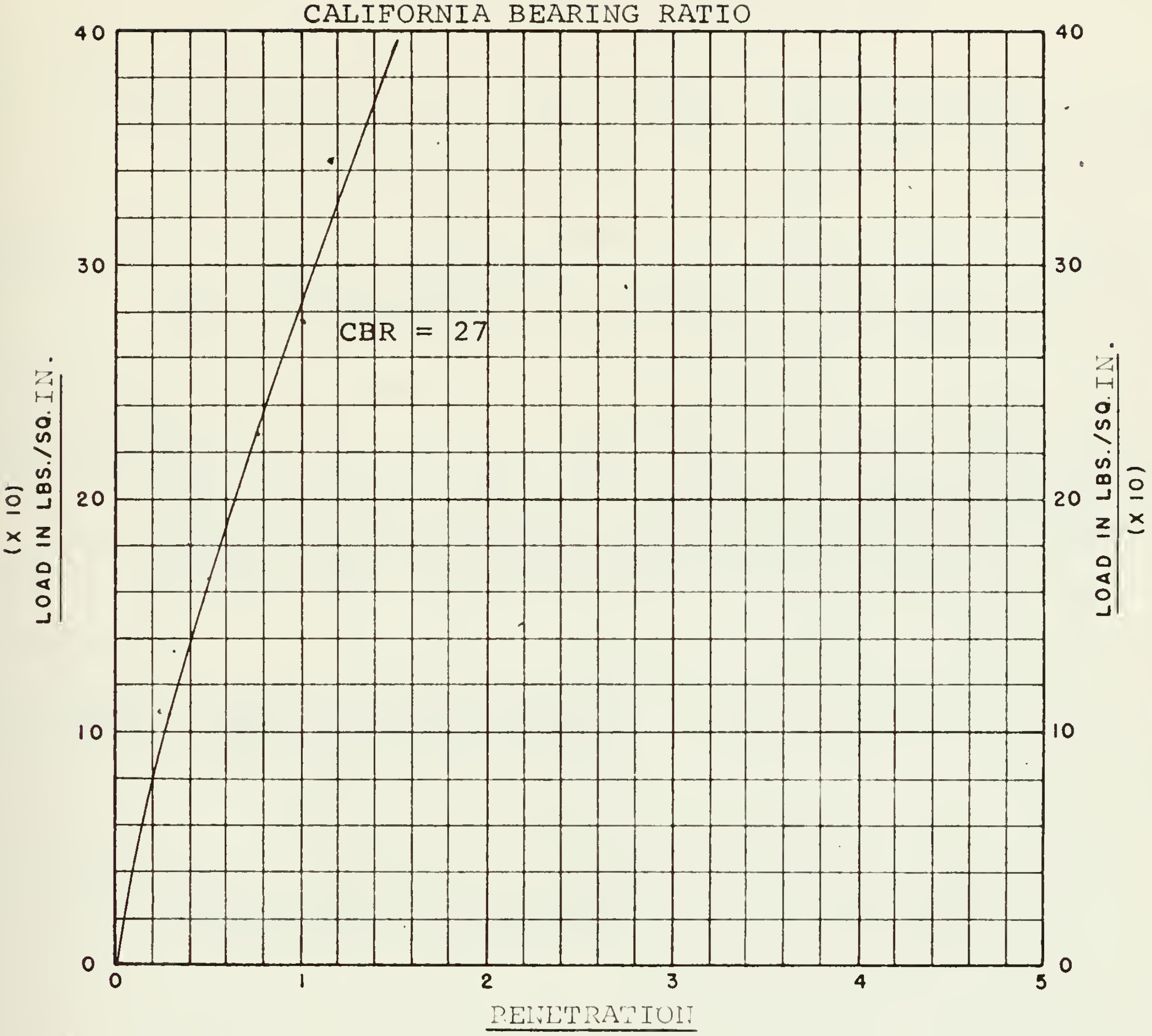
MOISTURE — DENSITY CURVE

TEST METHOD	T-99-D
OPTIMUM MOISTURE	8.8%
MAXIMUM DRY DENSITY	130.0 PCF

Liquid Limit	18
Plasticity Index	NP
#4	78
#200	26



Test Hole	Berry Creek TP 1, Sample #6
Depth	1'- 6'
Soil Type	Clayey Gravel
Moisture Initial	8.6%
Moisture Final	9.5%
Natural Dry Density	125 PCF



Test Hole	Berry Creek TP 4, Sample #8
Depth	4'- 6'
Soil Type	Green Clayey Gravel
Moisture Initial	8.2%
Moisture Final	9.1%
Natural Dry Density	126 PCF

BORROW SOURCE No. 2

Location: Stump Gulch in Sec. 34, T1S, R19E

Site: Non-irrigated pasture land, 0.4-0.8 miles northeast of right-of-way, Pierce Ranch property. Partially visible from Interstate.

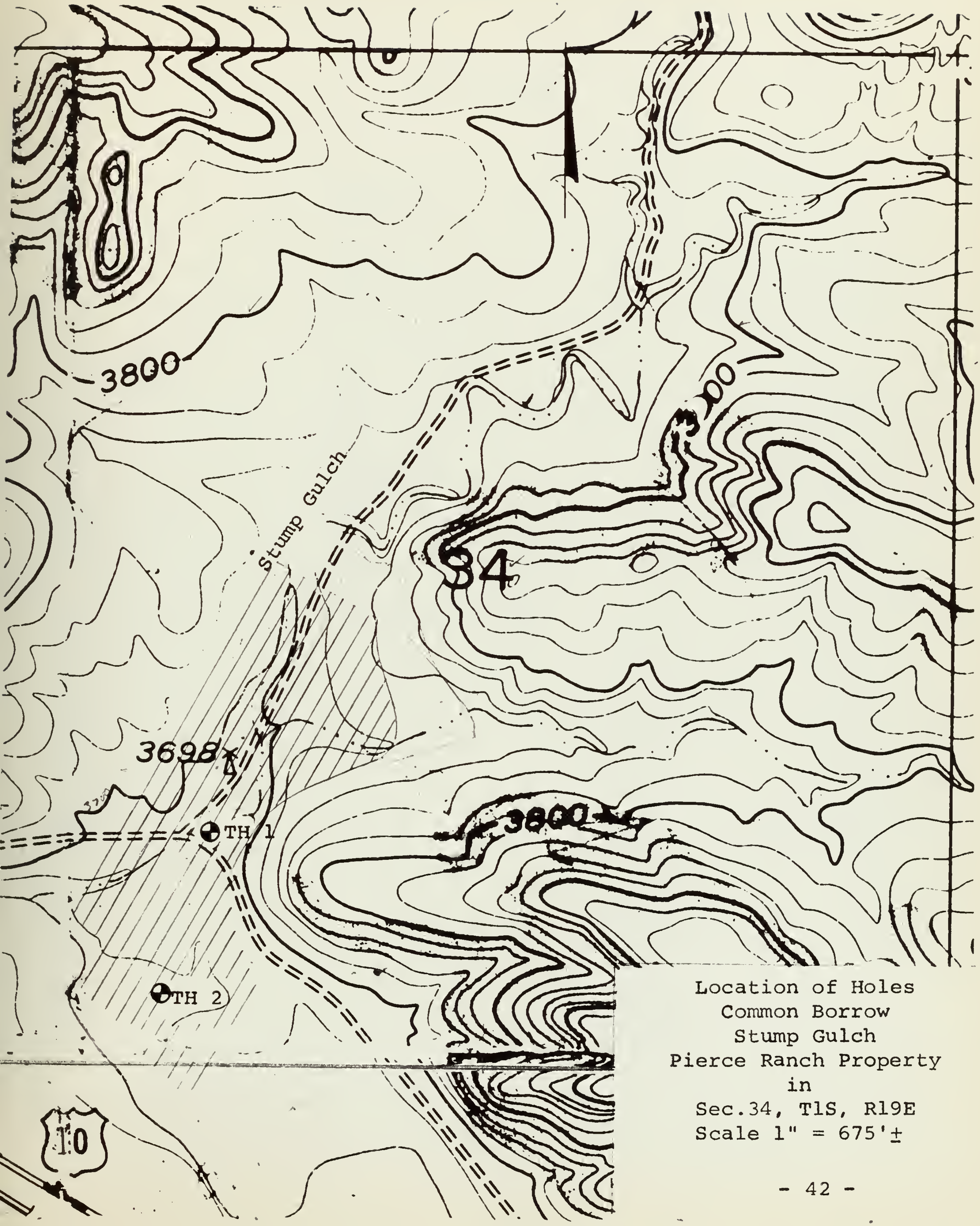
Access: By existing unimproved farm road terminating at Craver Interchange to the west and Cardwell school to the east. Haul to Interstate 0.4-0.8 miles to Sta. 575.

Quantities: Pasture lands . . . 1/4 million cu. yds.

Nature of Deposit: Silts, silty sand and gravels overlying weathered sandstone and shales. Overburden ranges up to one foot in depth. Material readily excavated to depths of 15-20 feet. Ground water not encountered within 25 feet.

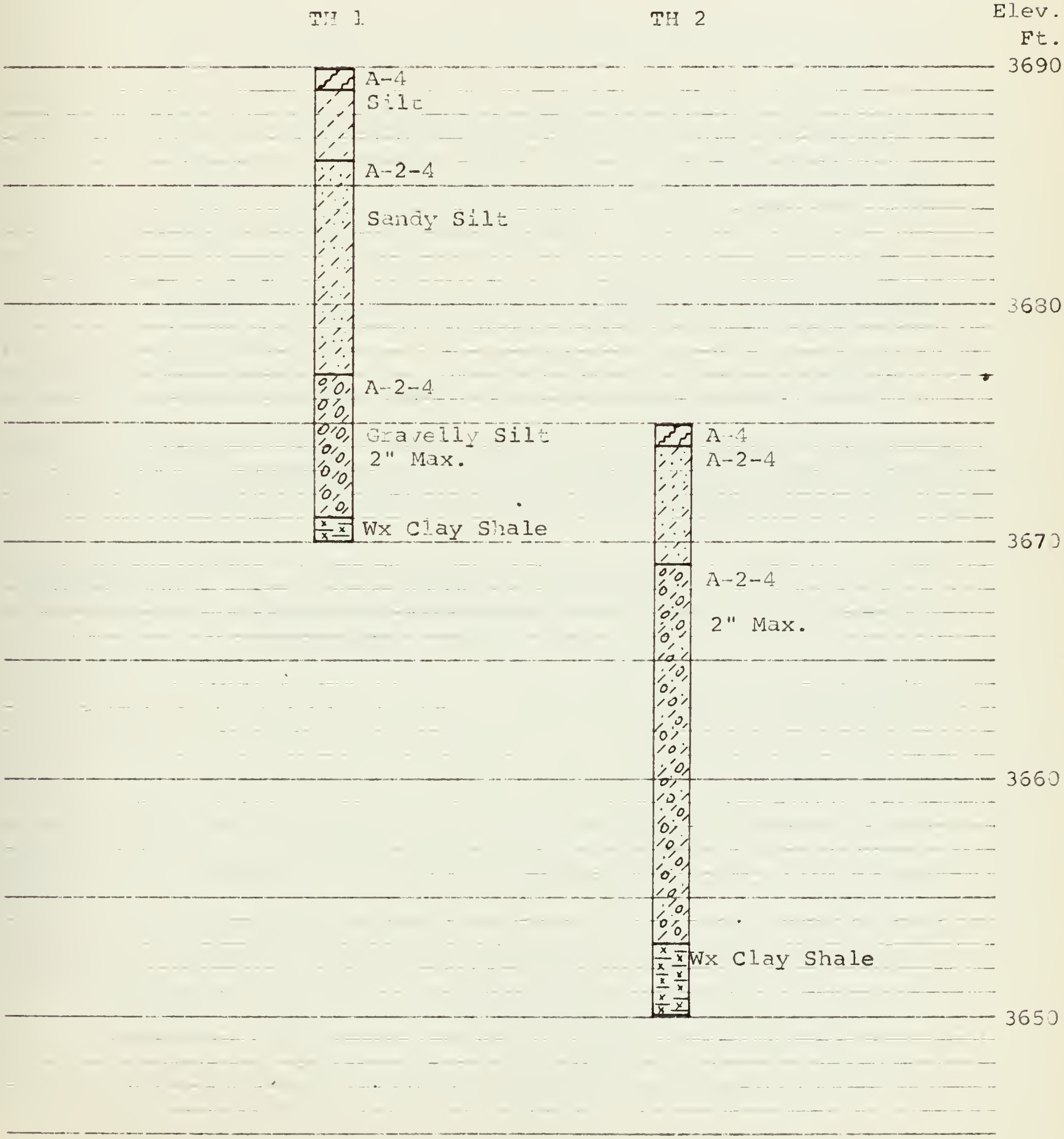
CBR Values:		
	Silty sands and gravels	15
	Weathered sandstones	15

Recommendations: This source is not desirable because it is visible from Interstate.



Location of Holes
Common Borrow
Stump Gulch
Pierce Ranch Property
in
Sec.34, T1S, R19E
Scale 1" = 675'±

Stamp Gulch Borrow
Test Holes



GRAVEL SOURCE No. 1

Location: Gravel terrace, south of Yellowstone River, Sec. 4, T2S, R19E , south of Springtime.

Site: Non-irrigated pasture land, 0.3-0.8 miles south of right-of-way. Goddard property. Not noticeable from Interstate.

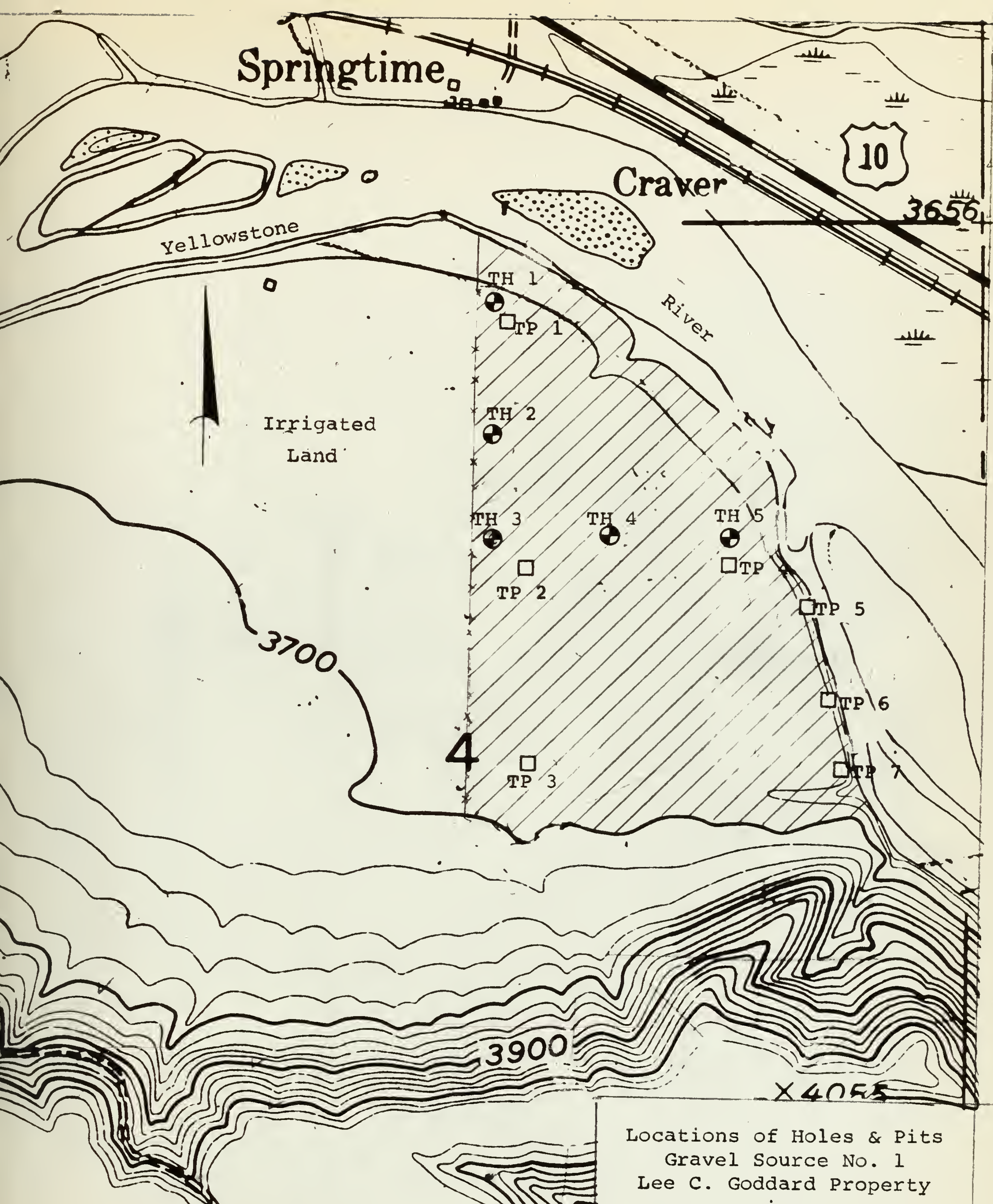
Access: Present access by unimproved existing farm road which enters U.S. 10 approximately four miles west of Craver Interchange. Consider a conveyor about 1500 feet long for access to the deposit across the Yellowstone River to Sta. 540. Conveyors with a capacity of 1000 tons per hour cost from $100 to $150 per running foot.

A temporary bridge would be subjected to fast water and floods. Railroad tracks run between the river and the Interstate.

Quantity: Terrace gravel above water, one million cubic yards.

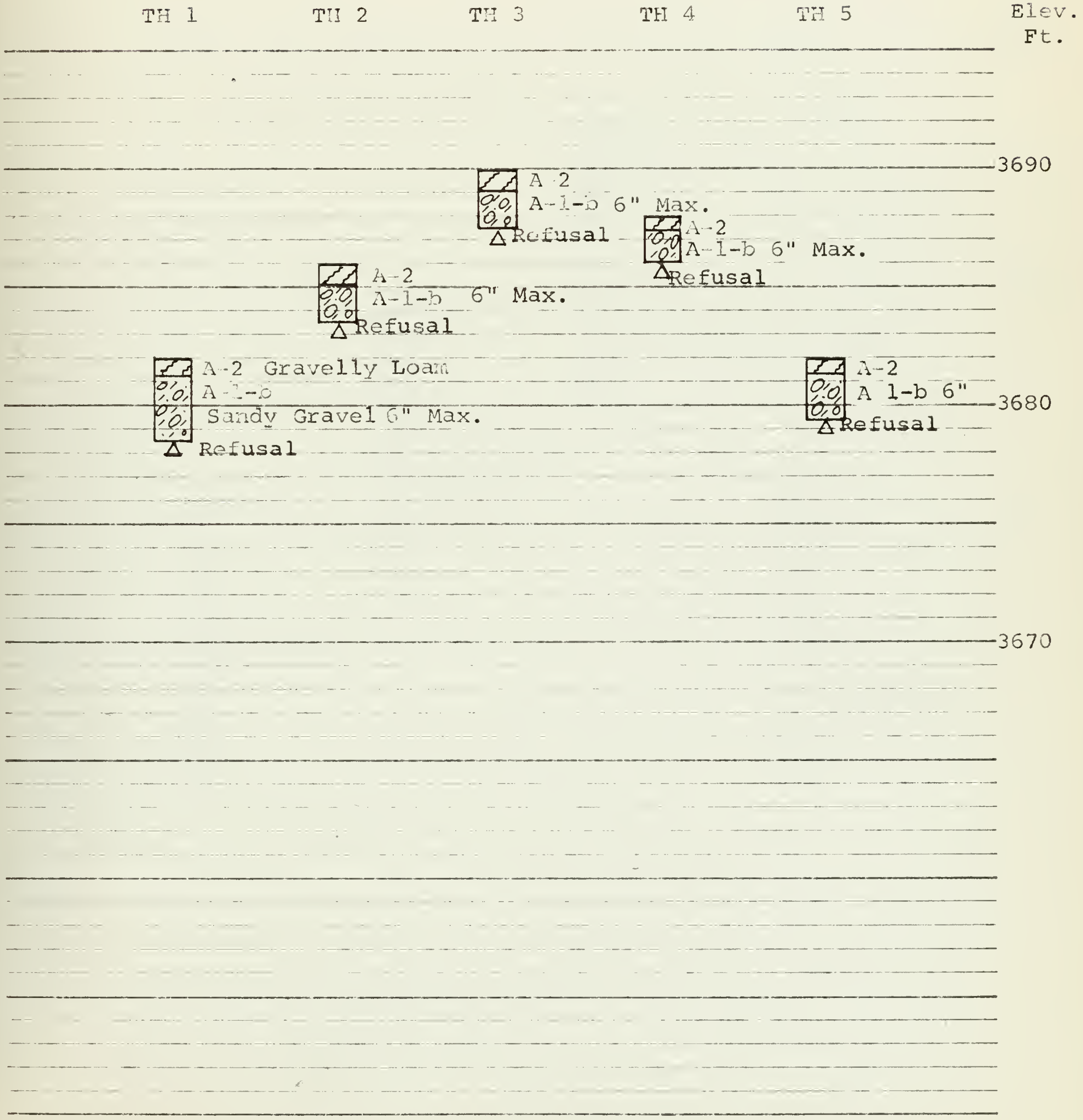
Nature of Deposit: Well-graded sound sandy gravel with an estimated 3% of material over 6 inches and a few boulders to 18 inches. Little or no overburden with scant vegetation. There are no clay seams.

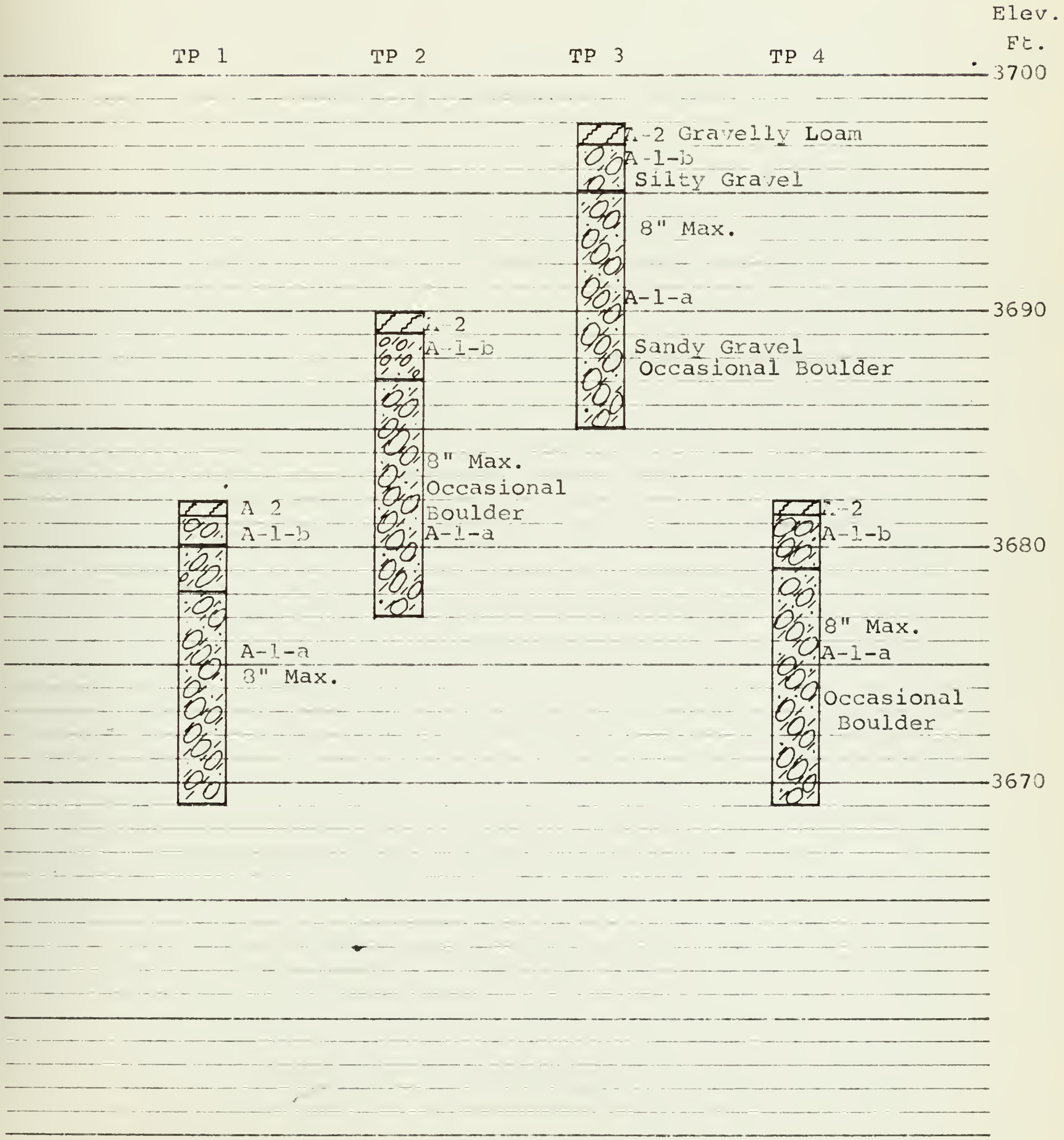
Potential Use: Plant Mix Bituminous Surfacing
Crushed Top Surfacing
Crushed Base Grade 2 and 5

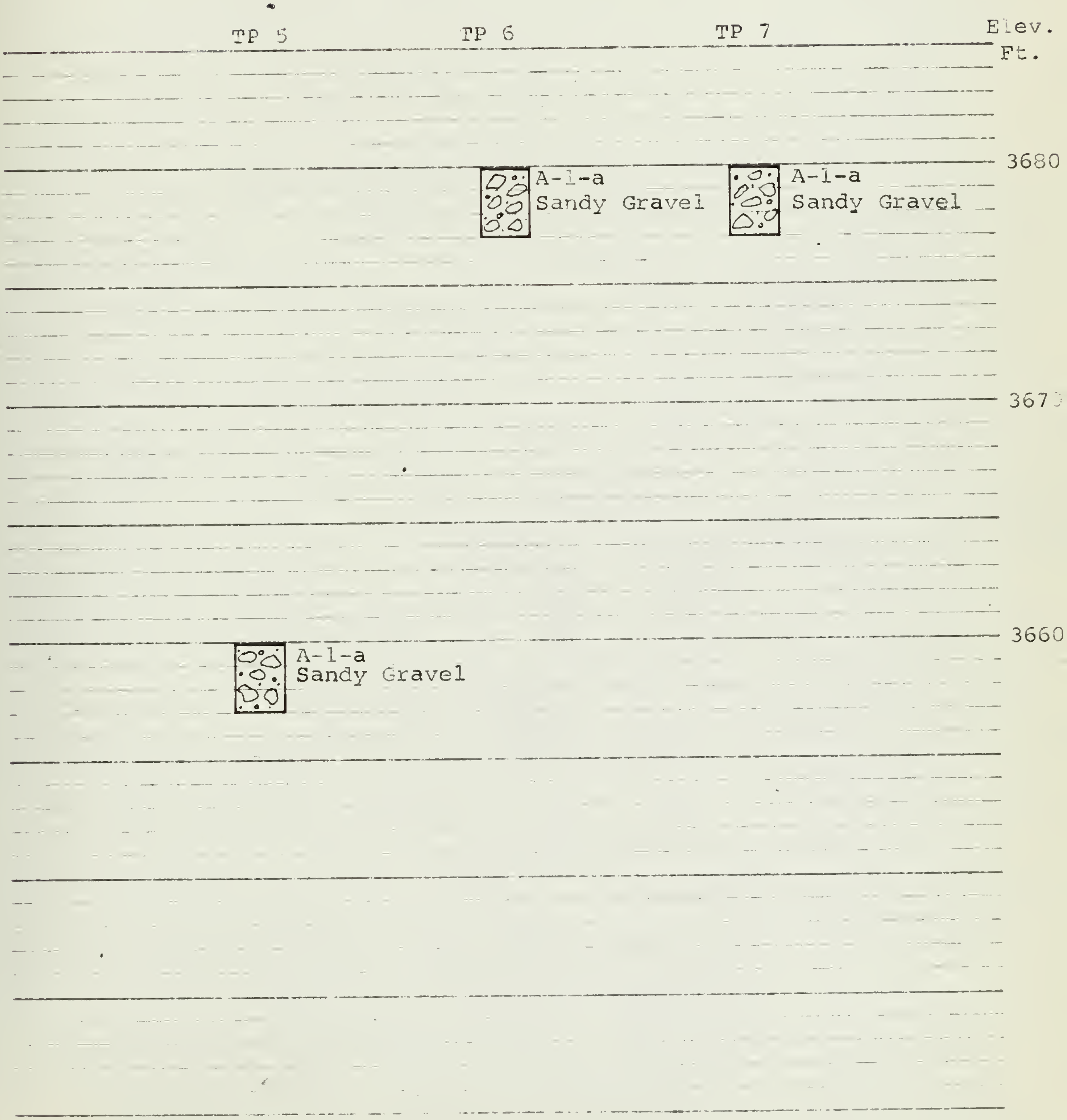


Locations of Holes & Pits
Gravel Source No. 1
Lee C. Goddard Property
in
E½ Sec.4, T2S, R19E
Scale 1" = 675'±

Test Holes


TH 1
TH 2
TH 3
TH 4
TH 5
Elev. Ft.
3690
3680
3670
A-2
A-1-b 6" Max.
Refusal
A-2
A-1-b 6" Max.
Refusal
A-2
A-1-b 6" Max.
Refusal
A-2 Gravelly Loam
A-1-b
Sandy Gravel 6" Max.
Refusal
A-2
A 1-b 6"
Refusal


Elev.
Ft.
TP 1
TP 2
TP 3
TP 4
3700
3690
3680
3670
A-2 Gravelly Loam
A-1-b
Silty Gravel
8" Max.
A-1-a
Sandy Gravel
Occasional Boulder
A-2
A-1-b
8" Max.
Occasional
Boulder
A-1-a
A 2
A-1-b
A-1-a
8" Max.
A-2
A-1-b
8" Max.
A-1-a
Occasional
Boulder


TP 5
TP 6
TP 7
Elev.
Ft.
3680
A-1-a
Sandy Gravel
A-1-a
Sandy Gravel
367
3660
A-1-a
Sandy Gravel

SUMMARY OF CONSULTANTS LABORATORY TESTS
AGGREGATE
GODDARD PROPERTY

Pit No.	1	1	2	2	2	2	3	4
Depth	2'	2-4'	1-2'	2'	6-8'	8-10'	2'	8-10'
Sieve Size Percent Passing								
Oversize	98	87	68		95	83		80
3"	83		62	92	79	78	94	77
1½"		74		66			86	
1"	58	65	35	40	43	35	69	42
#4	20	35	20	13	15	11	17	19
#10	17	32	18	11.4	12	9	12	16
#40	14	29	15	10	10	8	9	14
#200	3.2	9.6	5.5	4.9	2.7	3.4	3.5	4.3
Wear	18.7					16.6		17.3
Liquid Limit	NP	NP	NP	NP	NP	NP	NP	NP
Plast. Index	NP	NP	NP	NP	NP	NP	NP	NP

GRAVEL SOURCE No. 2 Explored by Montana Highway Commission

Location: Existing gravel pit areas in Sec. 5 and 6, T2S, R19E. Pierce Ranch properties on the west side of U.S. 10 Sta. 463.

Site: Cultivated farm land on the west side of and adjacent to the right-of-way. Existing pit areas are camouflaged, but any new workings will be visible from Interstate.

Access: Existing unimproved farm road accessible by underpass at Sta. 463.

Quantity: 1/4 million cubic yards above the grade of the underpass.

Nature of Deposit: Well-graded, sound, sandy gravel with 6 inch maximum size. Overburden is about 2.5 feet of loam and sandy silt. Water table is more than 20 feet below surface.

Potential Use: Plant Mix Bituminous Surfacing
Crushed Top Surfacing
Crushed Base Grade 2 and 5

FORM NO. 92 (REV. 1956)
20M-4-61

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Lab No. 346942-50

Sample [illegible]

County [illegible]

PIT REPORT

COMPLETE THIS FORM IN FULL. Mail three copies to the Testing Laboratory at Helena, and send one copy with the sample.

6
Project No. I-90-8(44)399 Designation [illegible] - [illegible] Reedpoint - East

Sample by Jack R Liedle Title Geologist 2

Address Billings Date Sampled 7/27/57

Type of Material Gravel Sample Tested for Proposed surfacing

Owner of Pit Pierce Ranches Inc. Address Billings, Montana

Jack Yurko, Pres.

Location of Pit (Give ¼ ¼ Sec.) Lots 4 & 5 & SE¼ NW¼ Sec 5, & SE¼ NE¼ Sec 6

T 2 S R 19 E

6
Pit is adjacent to Miles N - S / Feet E - W of Station 460+00 on Project I-90-8(44)390

Extent of Pit ft. × ft. = 477,000 sq. ft. = 10.95 acres

Thickness (Gravel) (Scoria) (Sand) (Above apparent water line 8.0 ft.) (Below apparent water line ft.) Total 8.0' average ft.

Probable cubic yards available 140,000 How much O/B on gravel? 2.3' average

Over 12" 0 % Between 12" and 6" 0 % Between 4" and 6" 2 % Less than 4" 98 %

For what is land used? Cultivated Is water available for washing? No

Deposit—Is it river, bank or bench gravel? Bench gravel

6
Haul Road * zero miles to sta. 460+00 on Project No. I-90-8(44)390

*(Measured to nearest 1/10 mile over practicable truck route to definite station on project)

Maximum grade zero Estimated cost of haul road none Condition

Type of existing bridges none Condition

Additional bridges required none

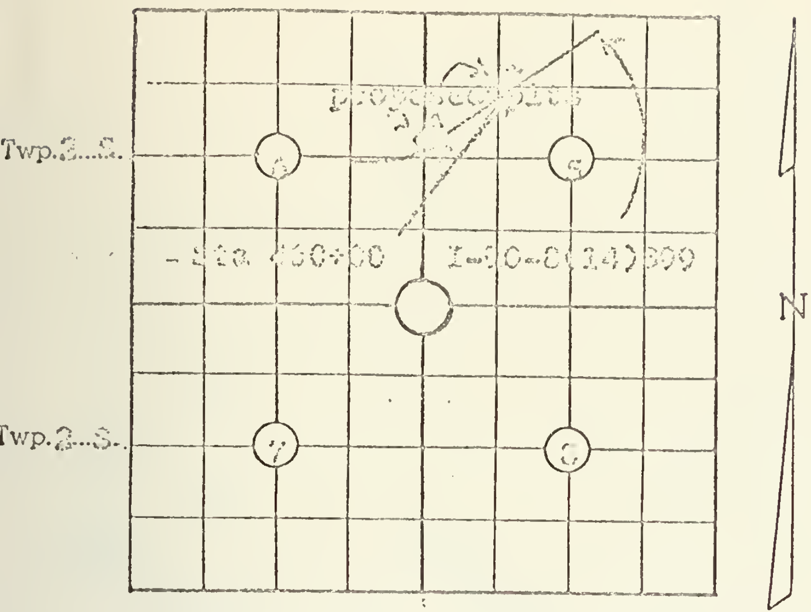
Haul road owner Address

(Name and address of owner of land crossed by haul road to a public highway)

18002, 18003, 18004, 18005, 18006, 18007, 18008, 18009, & 18010

Sec...5-6-8...... Twp...2...S. Range..16...E.....

Range.......16...E....... Range.....16..............



The accompanying sketch covers either one complete or four complete sections. In locating pit, use the section, or sections, which best permits the showing of the pit in an approximate relation to the project, haul road, etc. Use solid lines for indicating existing haul roads and dashed lines for proposed haul roads.

Minimum Sample Requirements

Up to 50,000 cys.	Min. of 3
50,000 - 100,000 cys.	3 to 5
100,000 - 150,000 cys.	5 to 8
150,000 - 200,000 cys.	8 to 10

No sample shall represent more than 3 test holes.

Sketch approximate outline of pit area, properly oriented as to direction, showing location of test holes. Show scale used. (Attach sketch on separate sheet if space provided hereon is insufficient.)

See attached sketch.

Note: The following test holes are logged as duds and fall outside of the pits; 1, 2, 3, 4, 5, 7, 8, 9, 13, 14, 15, & 21.

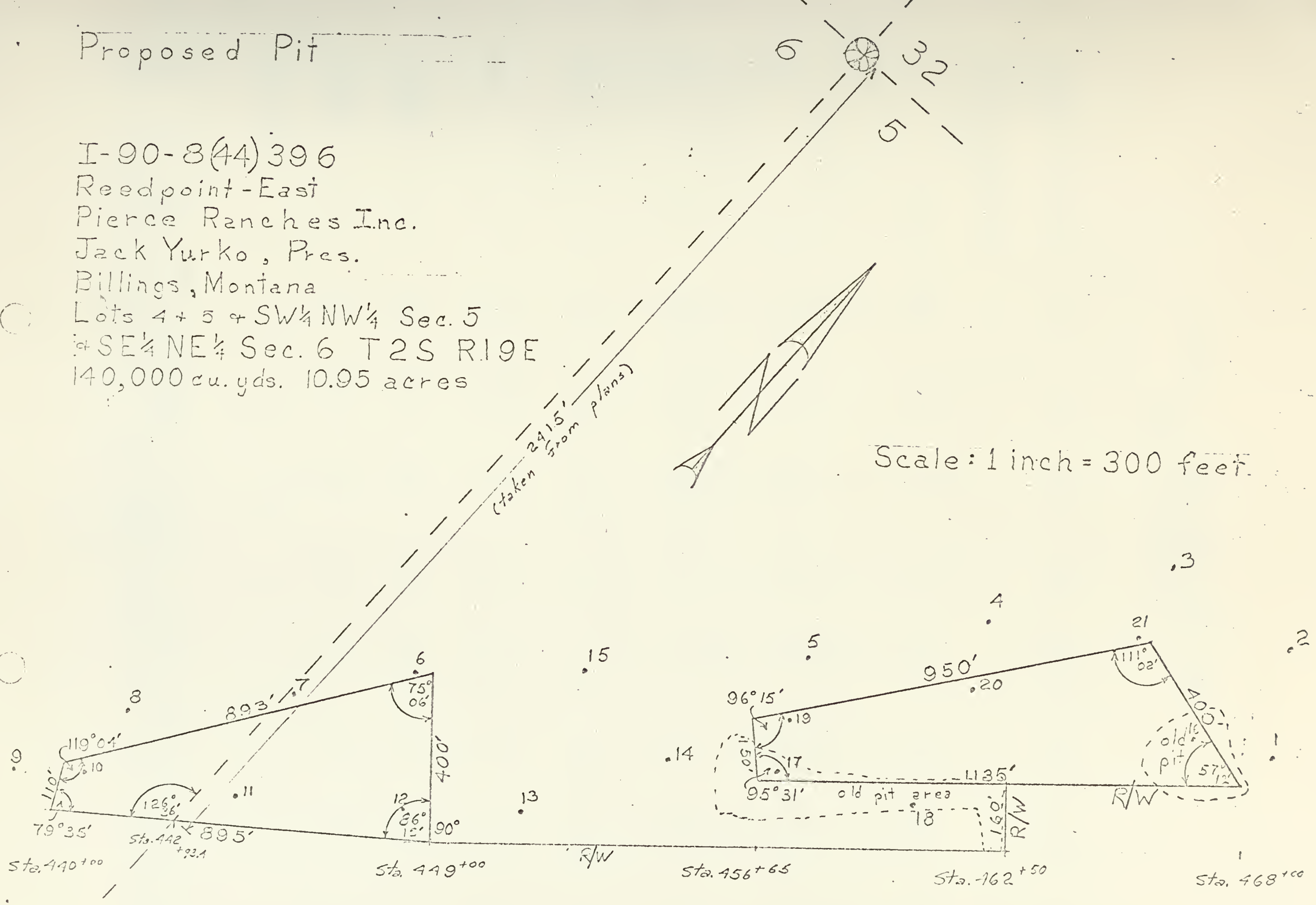
The volume of gravel available in this area, is considerably more than was actually proved, due to the extreme caving conditions of the test holes.

The information contained on this form should be complete enough to permit the preparation of a metes and bounds description or a legal description tied to project stationings.

mple No.	Test Hole		5 Ft.	10 Ft.	15 Ft.	20 Ft.	Legend for Hole Log
002	6	OB=6.5'	Gravel=	18.0'	Stop in grav		▨ Overburden
003	10	OB=3.5'	"	10.0'	" "	"	Gravel - Clean
004	11	OB=1.5'	"	8.0'	" "	"	Sand Strata
005	12	OB=2.0'	"	10.0'	" "	"	Silt
006	16	OB=0.0'	"	4.5'	Sand=7.5' " "	"	Clay Strata
007	17	OB 0.5'	"	6.5'	" "	"	Apparent Water Level
008	18	OB=0.0'	"	3.5'	[illegible]=5.5' Gravel=10.0'		and stop.
009	19	OB=3.0'	"	10.0'	Stop in grav		Oversize
[illegible]	20	Sand 5'	"	10.0'	" "	"	
mplary Hole Thus		▨					

Proposed Pit

I-90-8(44)396
Reedpoint-East
Pierce Ranches Inc.
Jack Yurko, Pres.
Billings, Montana
Lots 4 + 5 + SW¼ NW¼ Sec. 5
+ SE¼ NE¼ Sec. 6 T2S R19E
140,000 cu. yds. 10.95 acres



Scale: 1 inch = 300 feet

SUMMARY OF STATE LABORATORY TEST
AGGREGATE
PIERCE PIT SECTION 5

Sample No.	18002	18003	18004	18005	18006	18007	18008	18009	18010
Sieve Size Percent Passing									
Oversize			100	100	100		100		
3"	100	100	96	95	92	100	98	100	100
1½"	91	90	76	79	80	83	76	86	86
1"	86	79	67	71	73	69	65	75	77
#4	44	38	32	29	45	21	35	36	42
#10	34	33	27	23	39	16	31	29	38
#40	20	21	17	15	24	9	20	14	22
#100	10	14	11	9	5	4	8	5	6
#200	7.6	11.7	8.4	6.8	3.2	2.3	4.6	4.0	4.2
Wear	24	20	18	16	20	14	16	16	16
Liquid Limit	NP	NP	NP	NP	NP	NP	NP	NP	NP
Plast. Index	NP	NP	NP	NP	NP	NP	NP	NP	NP
Dry Swell 8 Day	3.6	3.6	3.6	3.6	1.7	3.5	3.4	1.7	1.6

Note: Current samples representing gravel at this location are covered by Lab. Nos. 346942 through 346950. Sampler advises that this deposit has 2.3 feet of overburden with 2% of the gravel between the 4 and 7 inch screens and the balance passing the 4 inch screen.

GRAVEL SOURCE No. 3 Explored by Montana Highway Commission

Location: Bottom lands on north side of Yellowstone River south of Craver in Sec. 3, T2S, R19E.

Site: Timbered and brushy flood plain pasture. 1/4 mile south of right-of-way on Pierce Ranch property. Visible from Interstate.

Access: Existing poor unimproved farm road from U.S. 10 east of Craver.

Quantity: 2/3 million cubic yards above water at time of drilling.

Nature of Deposit: Well-graded sound sandy gravel with 6 inch maximum size. Five to six feet of gravel above the water table overlain by 1.5 feet of silt and loam overburden.

Potential Use: Plant Mix Bituminous Surfacing
Crushed Top Surfacing
Crushed Base Grade 2 and 5

FORM NO. 92 (REV. 1956)
20M-1-61

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Lab No. 34/4118 - 4/44
Sample see below
County Stillwater

PIT REPORT

COMPLETE THIS FORM IN FULL. Mail three copies to the Testing Laboratory at Helena, and send one copy with the sample.

Project No. I-90-8(14)407 Designation Columbus - West

Sample by Jack R. Liedle Title Geologist 2

Address Billings Date Sampled 3/6/67

Type of Material Gravel Sample Tested for Proposed surfacing

Owner of Pit Pierce Ranch Inc. Address Billings, Montana
Jack Yurko, President

Location of Pit (Give ¼ ¼ Sec.) S½ NW¼ & SW¼ Sec 3 T 2 S R 19 E

Pit is 1500 feet South Miles N-S / Feet E-W of Station 599+00 on Project I-90-8(14)407

Extent of Pit ft. × ft. = "A"= 2,062,254 / "B"=231,202,361 sq. ft. = "A"= 47.34 / "B"= 27.61 acres

Thickness (Gravel) (Scoria) (Sand) (Above apparent water line "A"= 5.6 / "B"= 6.3 ft.) (Below apparent water line ft.) Total "A"= 5.6' average / "B"= 6.3' " ft.

Probable cubic yards available "A"= 400,000 / "B"= 250,000 How much O/B on gravel? "A"= 222.1' averag / "B"= 1.2' "

Over 12" 0 % Between 12" and 6" 0 % Between 4" and 6" 2 % Less than 4" 98 %

For what is land used? Grazing & feed yard Is water available for washing? Yes

Deposit—Is it river, bank or bench gravel? River gravel

Haul Road· *1500 feet miles to sta. 599+00 on Project No. I-90-8(14)407
*(Measured to nearest 1/10 mile over practicable truck route to definite station on project)

Maximum grade 2% Estimated cost of haul road $1000 Condition poor

Type of existing bridges None Condition

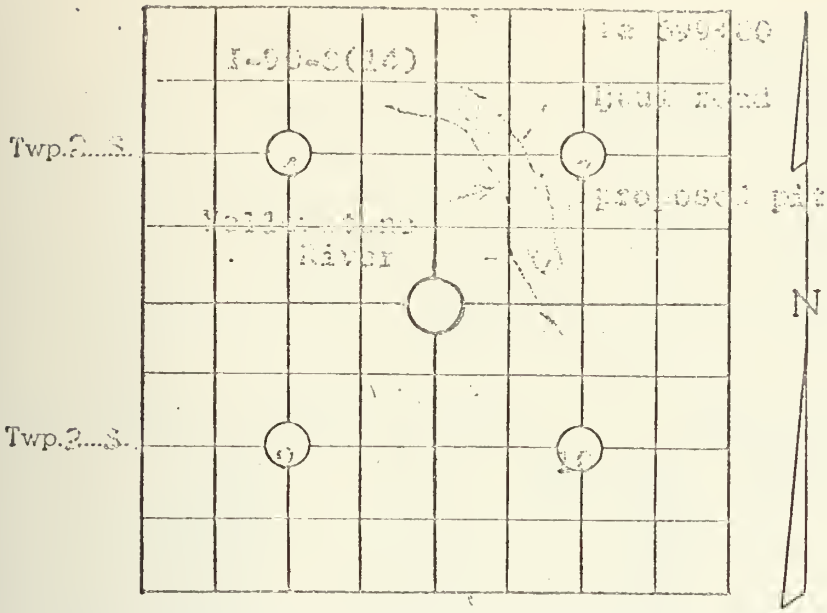
Additional bridges required 2 (culverts?)

Haul road owner Address
(Name and address of owner of land crossed by haul road to a public highway)

17240; 17242; 17244; 17246; 17248; 17250; 17252; 17254; 17256; 17258; 17260
17262; 17264; 17266; 17268; 17270; 17272; 17274; 17276; 17278; 17280; 17282
17284; 17286; 17288; 17290; 17292.

Sec. 3 Twp. [illegible] Range [illegible]

Range 17 E Range [illegible]



The accompanying sketch covers either one complete or four complete sections. In locating pit, use the section, or sections, which best permits the showing of the pit in an approximate relation to the project, haul road, etc. Use solid lines for indicating existing haul roads and dashed lines for proposed haul roads.

Minimum Sample Requirements

Up to 50,000 cys.	Min. of 3
50,000 - 100,000 cys.	3 to 5
100,000 - 150,000 cys.	5 to 8
150,000 - 200,000 cys.	8 to 10

No sample shall represent more than 3 test holes.

Sketch approximate outline of pit area, properly oriented as to direction, showing location of test holes. Show scale used. (Attach sketch on separate sheet if space provided hereon is insufficient.)

See attached sketch & sheet.

Note: The following holes were classed as duds and fall outside the pit boundaries= 5, 11, ~~38~~ 26, 34, 37, 41, 42 & 54

The following holes fall inside the pit boundaries, but were of insufficient gravel depth to warrant a sample= 12, 15, 23 & 28.

Note: the entire pit areas are not accessible for gravel production during the period of high-water (spring run-off).

Note: hole 27 falls outside the pit boundaries and no sample was taken, but was inadvertently given a ~~lab~~ field number (17259) which should be disregarded.

The information contained on this form should be complete enough to permit the preparation of a metes and bounds description or a legal description tied to project stationings.

Sample No.	Test Hole	5 Ft. 10 Ft. 15 Ft. 20 Ft.
17240	2	OB= 2.5' gravel= 7.5' stop in wet gravel
17242	4	" 4.5' " 4.5' " " " "
17244	7	" 1.0' " 9.0' " " " "
17246	9	" 0.5' " 6.5' " " " "
17248	13	" 1.0' " 8.5' " " " "
17250	16	" 4.0' " [illegible] " " " "
[illegible]	[illegible]	" [illegible] " [illegible] " " " "
17254	20	" [illegible] " [illegible] " " " "
17256	22	" 2.0' " [illegible] " " " "

Legend for Hole Log

- ⋘ Overburden
- ▨ Gravel - Clean
- ⁘ Sand Strata
- ▨ Silt
- ▨ Clay Strata
- ⌇ Apparent Water Level
- ○ Oversize

Exemplary Hole.
Log Thus

34118

I-90-8(14)407 Columbus - West

Pierce Ranch Inc. Billings, Montana

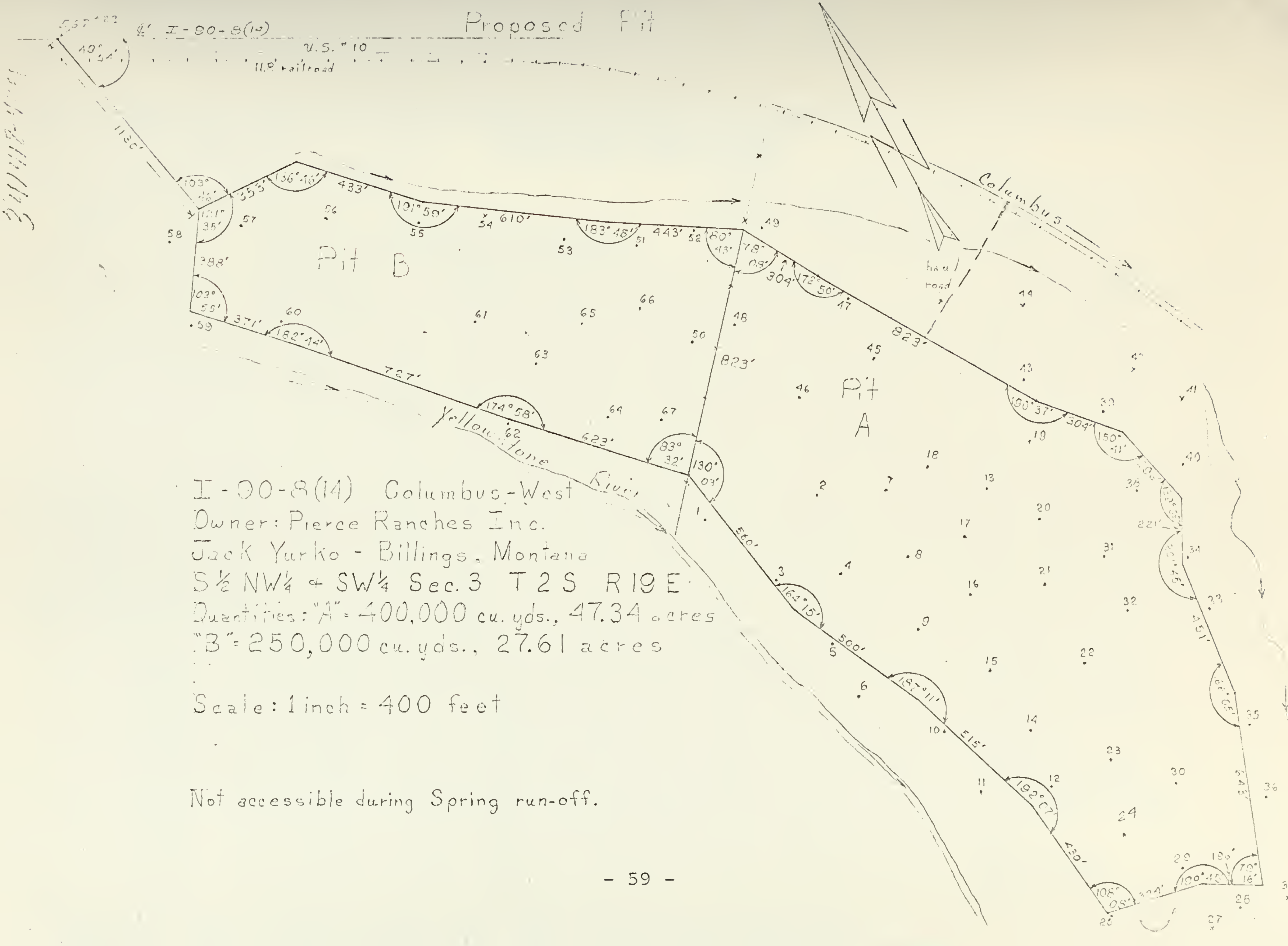
S½ NW¼ & SW¼ Sec 3 T 2 S R 19 E

Area= "A" - 47.34 acres, "B" = 27.61 acres.

Vaolume= "A"- 400,000 cu. yds., "B" - 250,000 cu. yds.

Sample No.	Test Hole	Log of Hole (continued)							
17258	28	OB=	2.0'	Gravel=	6.0'	Stop	in	wet	gravel.
17260	30	"	1.0'	"	6.0'	"	"	"	"
17262	32	"	4.5'	"	4.5'	"	"	"	"
17264	35	"	0.0'	"	6.5'	"	"	"	"
17266	38	"	0.0'	"	6.5'	"	"	"	"
17268	40	"	0.5'	"	5.0'	"	"	"	"
17270	448	"	1.5'	"	5.5'	"	"	"	"
17272	46	"	3.0'	"	5.0'	"	"	"	"
17274	48	"	0.5'	"	5.5'	"	"	"	"
17276	50	"	0.5'	"	8.5'	"	"	"	"
17278	52	"	0.0'	"	5.5'	"	"	"	"
17280	55	"	0.5'	"	7.0'	"	"	"	"
17282	57	"	0.5'	"	7.5'	"	"	"	"
17284	59	"	1.0'	"	6.0'	"	"	"	"
17286	61	"	2.5'	"	6.0'	"	"	"	"
17288	63	"	1.0'	"	4.5'	"	"	"	"
17290	65	"	1.0'	"	8.0'	"	"	"	"
17292	67	"	1.5'	"	7.0'	"	"	"	"

Proposed Pit



I-90-8(14) Columbus-West
Owner: Pierce Ranches Inc.
Jack Yurko - Billings, Montana
S½ NW¼ + SW¼ Sec. 3 T 2 S R 19 E
Quantities: "A" = 400,000 cu. yds., 47.34 acres
"B" = 250,000 cu. yds., 27.61 acres

Scale: 1 inch = 400 feet

Not accessible during Spring run-off.

3 4/11/5

Form No. 99

Montana State Highway Commission
FIELD SAMPLE ANALYSIS REPORT

Sheet 1 of 3

Date March 16, 1967

Division Billings

Submitted By Jack R. Liedle

Title Geologist 2

Sampled For Proposed surfacing
(Surfacing, Borrow, Sand Base etc.)

Project No. I-90-8(14)407

Location Columbus - West

Estimated Quantity In Deposit 650,000 cu. yds.

Owner Pierce Ranch Inc.

Address Billings, Montana

Test Hole No.	Branch Lab. or Field No.	Oversize	Depth Of Sample In Feet	Oversize		Grading Of -4" Fraction Percent Passing												Mesh Fraction		
				6"	4to6"	4"	3"	2"	1½"	1"	3/4"	1/2"	#4	#10	#40	#80	#200	L.L	P.L.	P.I.
1	17239	0	4.0 to 11.5	0	0	100	95	88	82	67	59	49	35	31	23	11	5.7	NP	NP	NP
3	17241	0	3.0 to 9.5	0	0	100	93	80	69	55	46	36	27	26	18	8	4.4	NP	NP	NP
6	17243	0	3.0 to 9.0	0	0	100	93	74	64	48	40	31	22	20	16	8	3.6	NP	NP	NP
8	17245	0	1.5 to 6.5	0	0	100	91	80	72	59	53	47	36	30	22	9	4.0	NP	NP	NP
10	17247	0	3.5 to 8.5	0	0	100	96	90	85	73	65	55	37	30	22	13	7.1	NP	NP	NP
14	17249	0	4.0 to 8.0	0	0	100	98	91	79	62	53	44	30	25	19	13	7.2	NP	NP	NP
17	17251	0	1.0 to 8.0	0	0	100	94	81	74	64	60	54	45	40	31	10	4.1	NP	NP	NP
19	17253	0	0.0 to 9.0	0	0	100	100	88	80	67	55	43	23	17	9	3	1.6	NP	NP	NP
21	17255	0	1.5 to 8.0	0	0	100	95	84	76	64	54	44	31	28	21	9	4.3	NP	NP	NP

Test Hole	Sample No.		5 Ft.		10 Ft.	15 Ft.	20 Ft.	25 Ft.
1	17239	OB=	4.0	Gravel=	7.5	Stop in	wet gravel	
3	17241	"	3.0	"	6.5	"	" "	
6	17243	"	3.0	"	6.0	"	" "	
8	17245	"	1.5	"	5.0	"	" "	
10	17247	"	3.5	"	5.0	"	" "	
14	17249	"	4.0	"	4.0	"	" "	
17	17251	"	1.0	"	7.0	"	" "	
19	17253	"	0.0	"	9.0	"	" "	
21	17255	"	1.5	"	6.5	"	" "	

▨	Overburden
▨	Gravel, Clean
▨	Sand Strata
▨	Silt
▨	Clay Strata
≷	Apparent Water Level
○	Oversize

Report here results of all tests made in the Field or in the Branch Laboratory.
Should some tests be delayed, submit results later on this form with the same description.

Form No. 99

Sheet 2 of 3

Montana State Highway Commission
FIELD SAMPLE ANALYSIS REPORT

Date March 16, 1967
Division Billings
Submitted By Jack R. Liedle
Title Geologist 2
Sampled For Proposed surfacing
(Surfacing, Borrow, Sand Base etc.)

Project No. ZBS I-90-8(14)407
Location Columbus - West
Estimated Quantity In Deposit 650,000 cu. yds.
Owner Pierce Ranch Inc.
Address Billings, Montana

Test Hole No.	Branch Lab. or Field No.	Oversize	Depth Of Sample In Feet	Oversize		Grading Of -4" Fraction Percent Passing												Mesh Fraction		
				6"	4to6"	4"	3"	2"	1½"	1"	3/4"	1/2"	#4	#10	#40	#80	#200	L.L	P.L.	P.I.
25	17257	0	1.5to7.5	0	0	100	90	87	84	69	59	49	42	40	34	14	5.9	NP	NP	NP
29	17261	0	6.0to12.0	0	0	100	100	98	92	75	66	55	40	34	27	15	4.7	NP	NP	NP
31	17263	0	1.0to8.0	0	0	100	100	90	82	69	60	50	41	39	31	10	2.5	NP	NP	NP
33	17265	0	0.0to8.0	0	0	100	100	86	77	63	53	42	27	23	15	6	2.2	NP	NP	NP
36	17267	0	0.0to6.0	0	0	100	97	88	82	67	58	47	31	24	17	6	3.1	NP	NP	NP
39	17269	0	1.0to6.0	0	0	100	93	87	75	60	52	40	27	23	18	8	4.3	NP	NP	NP
43	17271	0	0.5to6.5	0	0	100	96	81	68	55	48	37	25	22	17	8	4.0	NP	NP	NP
45	17273	0	0.5to6.5	0	0	100	92	88	76	58	47	38	31	30	24	10	5.3	NP	NP	NP
47	17275	0	1.5to7.0	0	0	100	100	84	78	63	55	45	34	29	24	16	7.8	NP	NP	NP

Test Hole	Sample No.	5 Ft.		10 Ft.		15 Ft.		20 Ft.		25 Ft.
25	17257	OB=	1.5	Gravel=	6.0	Stop	in	wet	gravel.	
29	17261	"	6.0	"	6.0	"	"	"	"	
31	17263	"	1.0	"	7.0	"	"	"	"	
33	17265	"	0.0	"	8.0	"	"	"	"	
36	17267	"	0.0	"	6.0	"	"	"	"	
39	17269	"	1.0	"	5.0	"	"	"	"	
43	17271	"	0.5	"	6.0	"	"	"	"	
45	17273	"	0.5	"	6.0	"	"	"	"	
47	17275	"	1.5	"	5.5	"	"	"	"	

▨	Overburden
▨	Gravel, Clean
▨	Sand Strata
▨	Silt
▨	Clay Strata
⌇	Apparent Water Level
○	Oversize

Report here results of all tests made in the Field or in the Branch Laboratory.
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Form No. 99

Date March 16, 1967

Division Billings

Submitted By Jack R. Liedle

Montana State Highway Commission
FIELD SAMPLE ANALYSIS REPORT

Sheet 3 of 3

Project No. I-90-8(14)407

Location Columbus - West

Title Geologist 2

Sampled For Proposed surfacing
(Surfacing, Borrow, Sand Base etc.)

Estimated Quantity In Deposit 650,000 cu. yds.

Owner Pierce Ranch Inc.

Address Billings, Montana

Test Hole No.	Branch Lab. or Field No.	Oversize	Depth Of Sample In Feet	Oversize		Grading Of -4" Fraction						Percent Passing						Mesh Fraction		
				6"	4to6"	4"	3"	2"	1½"	1"	3/4"	1/2"	#4	#10	#40	#80	#200	L.L	P.L.	P.I.
49	17277	0	1.0 to 5.5	0	0	100	96	76	73	60	46	35	25	25	17	5	2.8	NP	NP	NP
51	17279	0	2.0 to 8.0	0	0	100	100	96	87	77	70	62	55	54	42	14	5.9	NP	NP	NP
53	17281	0	0.0 to 7.5	0	0	100	100	91	82	64	52	38	22	17	8	3	1.1	NP	NP	NP
56	17283	0	2.0 to 8.5	0	0	100	100	92	81	65	52	39	27	24	15	6	2.7	NP	NP	NP
58	17285	0	0.0 to 6.0	0	0	100	95	87	80	68	59	47	29	23	14	7	3.8	NP	NP	NP
60	17287	0	1.0 to 6.0	0	0	100	90	80	76	62	53	46	32	28	21	12	6.5	NP	NP	NP
62	17289	0	1.5 to 8.5	0	0	100	95	84	72	55	45	38	32	30	25	9	2.9	NP	NP	NP
64	17291	0	2.0 to 6.0	0	0	100	100	91	82	69	62	54	39	34	24	15	9.5	NP	NP	NP
66	17293	0	3.0 to 10.5	0	0	100	94	85	80	65	58	48	37	33	21	9	4.8	NP	NP	NP

Test Hole	Sample No.			5 Ft.	10 Ft.		15 Ft.		20 Ft.	25 Ft.
49	17277	OB=	1.0	Gravel=	4.5	Stop	In	wet	gravel.	
51	17279	"	2.0	"	6.0	"	"	"	"	
53	17281	"	0.0	"	7.5	"	"	"	"	
56	17283	"	2.0	"	6.5	"	"	"	"	
58	17285	"	0.0	"	6.0	"	"	"	"	
60	17287	"	1.0	"	5.0	"	"	"	"	
62	17289	"	1.5	"	7.0	"	"	"	"	
64	17291	"	2.0	"	4.0	"	"	"	"	
66	17293	"	3.0	"	7.5	"	"	"	"	

Overburden
Gravel, Clean
Sand Strata
Silt
Clay Strata
Apparent Water Level
Oversize

Report here results of all tests made in the Field or in the Branch Laboratory.
Should some tests be delayed, submit results later on this form with the same description.

SUMMARY OF STATE LABORATORY TESTS
AGGREGATE
PIERCE PIT SECTION 3

Sample Nos.	17240	17242	17244	17246	17248	17250	17252	17254	17256
Sieve Size Percent Passing									
Oversize		100	100		100		100	100	
3"	100	96	96	100	92	100	91	97	100
1½"	82	75	69	83	71	79	71	77	85
1"	71	67	61	71	59	69	61	68	70
#4	29	39	31	35	34	42	31	39	38
#10	23	34	25	31	33	39	28	36	34
#40	15	26	20	25	28	29	21	26	23
#100	7	11	8	9	9	17	8	10	8
#200	4.1	5.8	4.9	6.0	4.1	9.6	4.5	5.8	3.4
Wear	14	15	16	18	16	18	16	17	18
Liquid Limit	NP	NP	NP	NP	NP	NP	NP	NP	NP
Plast. Index	NP	NP	NP	NP	NP	NP	NP	NP	NP
Dry Swell 8 Day	3.4	3.3	3.3	3.4	3.3	3.4	4.3	3.4	3.4

Note: Current samples representing gravel at this location are covered by Lab. Nos. 341418 through 314444. Sampler advises that this deposit has an average of 1.65 feet of overburden with 2% of the gravel between the 4 and 6 inch screens and the balance passing the 4 inch screen.

SUMMARY OF STATE LABORATORY TESTS
AGGREGATE
PIERCE PIT SECTION 3

Sample Nos. Sieve Size Percent Passing	17258	17260	17262	17264	17266	17268	17270	17272	17274
Oversize	100	100					100		
3"	97	95	100	100	100	100	96	100	100
1½"	69	73	89	85	88	86	67	77	75
1"	59	61	78	74	74	70	55	68	60
#4	33	36	39	42	36	22	32	37	37
#10	28	35	36	41	32	16	27	31	35
#40	20	24	26	32	23	12	22	26	27
#100	8	8	4	12	5	6	6	13	14
#200	5.0	3.9	1.9	6.3	2.1	3.3	3.8	7.7	8.0
Wear	15	16	16	17	14	14	15	16	18
Liquid Limit	NP	NP	NP	NP	NP	NP	NP	NP	NP
Plast. Index	NP	NP	NP	NP	NP	NP	NP	NP	NP
Dry Swell 8 Day	1.8	5.1	4.8	5.8	4.9	6.8	5.0	5.2	7.1

SUMMARY OF STATE LABORATORY TESTS
AGGREGATE
PIERCE PIT SECTION 3

Sample Nos.	17276	17278	17280	17282	17284	17286	17288	17290	17292
Sieve Size Percent Passing									
Oversize	100					100	100		
3"	94	100	100	100	100	96	76	100	100
1½"	76	84	87	77	77	74	61	82	84
1"	63	75	71	64	64	65	54	70	69
#4	32	40	30	22	38	35	36	36	41
#10	27	30	25	18	36	28	34	28	37
#40	16	14	17	14	23	16	27	22	28
#100	4	4	3	3	5	6	9	12	6
#200	2.2	2.0	1.8	1.7	1.9	3.5	4.4	7.8	3.3
Wear	16	18	18	16	16	17	14	16	16
Liquid Limit	NP	NP	NP	NP	NP	NP	NP	NP	NP
Plast. Index	NP	NP	NP	NP	NP	NP	NP	NP	NP
Dry Swell 8 Day	5.0	6.8	4.8	4.9	4.8	7.0	4.9	7.0	4.8

BRIDGE

Location: Station 463

Type of Structure: Junior interchange with concrete box culvert underpass for a farm road. Existing culvert beneath the eastbound lanes to be extended under the new westbound lanes.

Site: This site is located on the edge of an elevated gravel terrace of the Yellowstone River. An appreciable amount of gravel has been mined from the deposit west and north of the site. The gravel extends westward about 400 feet from the right-of-way.

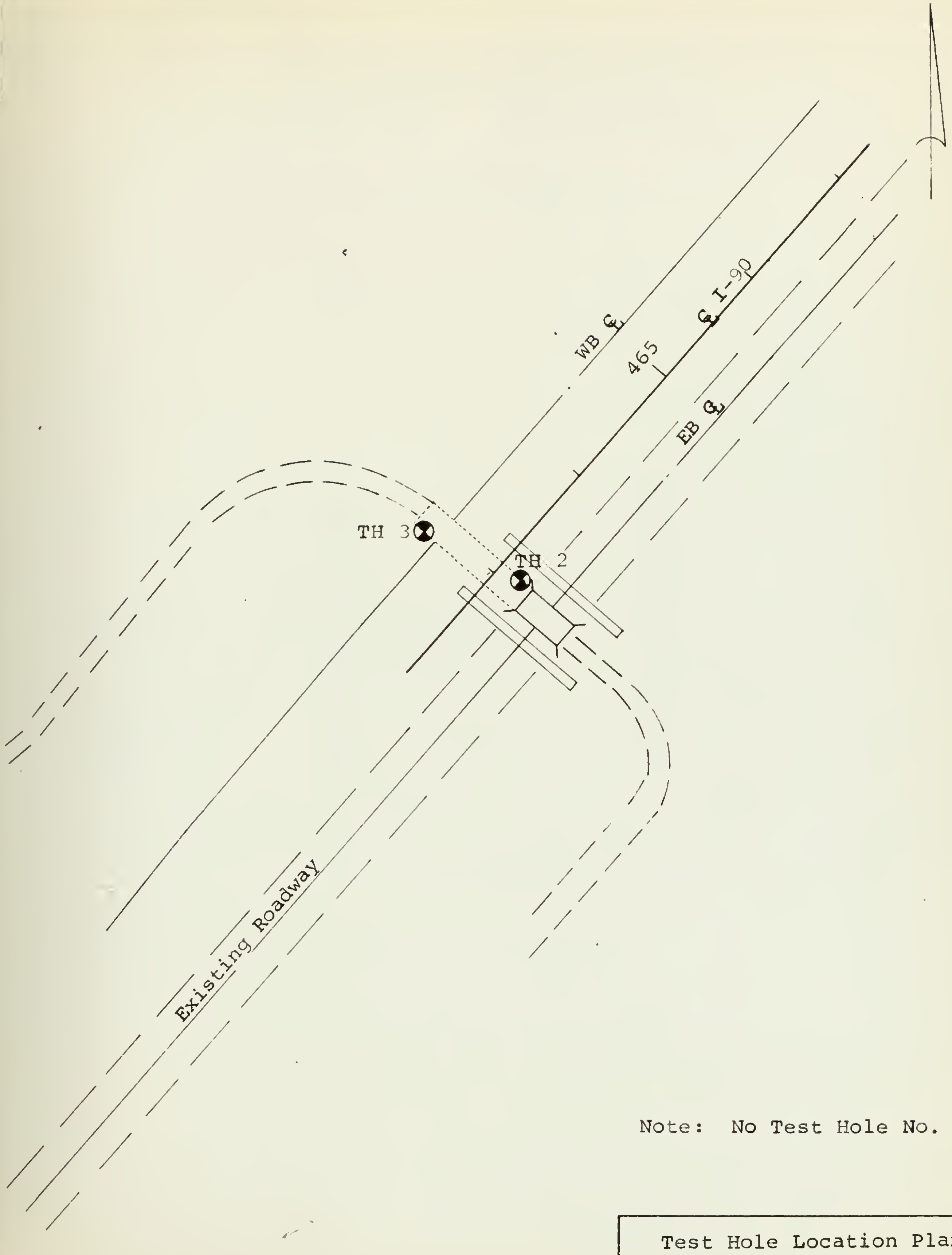
The existing culvert under the eastbound lanes, supported by piling, is located on the edge of the terrace. Gravels are overlain by varying amounts of silty overburden soils.

Investigation: Two test borings were made using truck-mounted power-driven continuous auger. Standard penetration tests were made as the borings were advanced to refusal.

Findings: Well-graded sandy gravels are present at surface and extend below the 13.5 foot depth investigated. Ground water was not encountered.

Recommendations: Footings should bear on sandy gravels at sufficient depth to provide 36 inches of frost cover at the wing walls. Maximum allowable soil pressure is 10 ksf.

Type I cement will be satisfactory for use in concrete exposed to soils or weather.



Note: No Test Hole No. 1

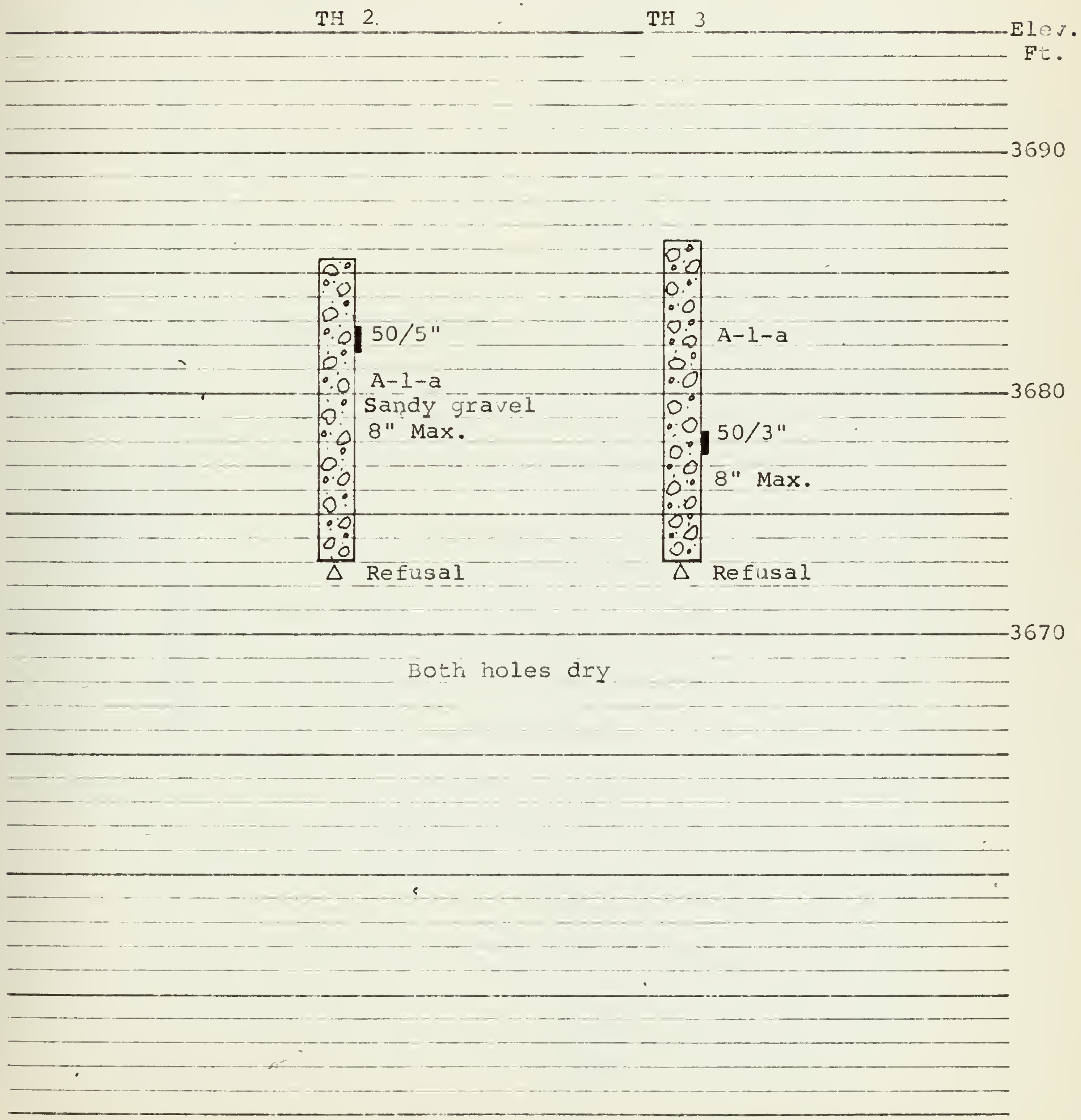
Test Hole Location Plan
Junior Grade Separation
Station 463+00

Scale 1" = 100'

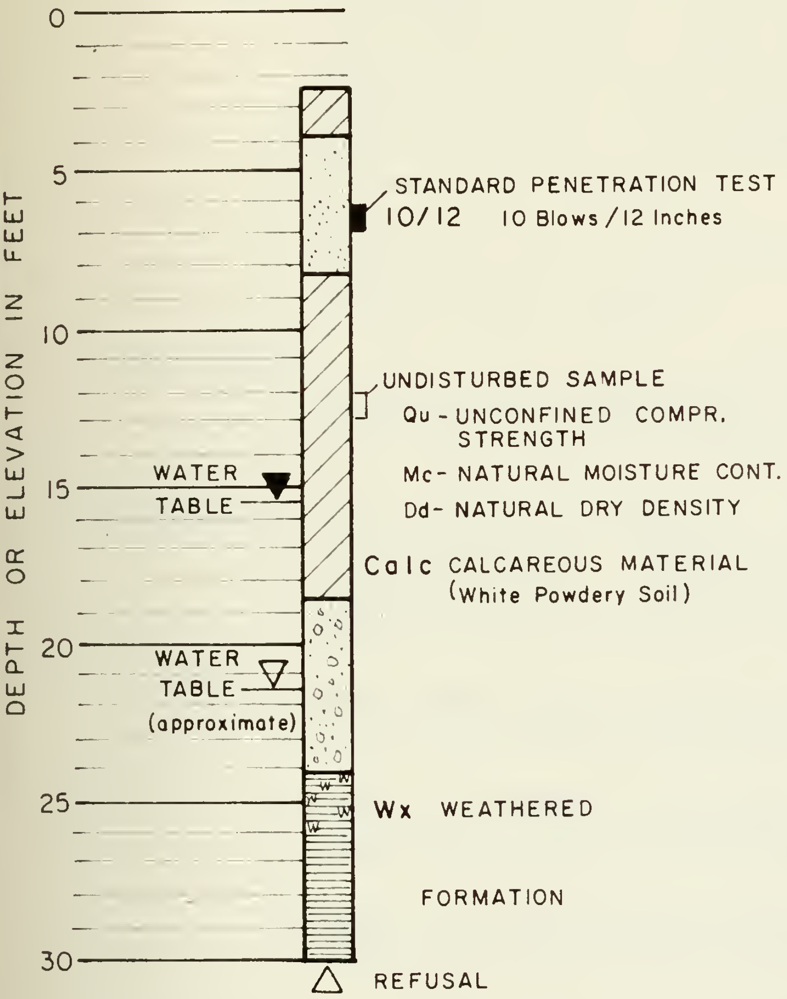
PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Junior Grade Separation
Boring Logs



TYPICAL TEST HOLE LOG


DEPTH OR ELEVATION IN FEET
0
5
10
15
20
25
30
STANDARD PENETRATION TEST
10/12 10 Blows / 12 Inches
UNDISTURBED SAMPLE
Qu - UNCONFINED COMPR. STRENGTH
Mc - NATURAL MOISTURE CONT.
Dd - NATURAL DRY DENSITY
WATER TABLE
Calc CALCAREOUS MATERIAL (White Powdery Soil)
WATER TABLE (approximate)
Wx WEATHERED
FORMATION
REFUSAL

SYMBOLS

SYMBOL		DESCRIPTION - AASHO
⁘	A-1-a	WELL-GRADED CLEAN GRAVELS
⁘	A-1-b	POORLY GRADED CLEAN GRAVELS
▨	A-1-b A-2-4	GRAVEL-SAND-SILT MIXTURES
▨	A-1-b A-2-6	GRAVEL-SAND-CLAY MIXTURES
░	A-1-b	WELL GRADED SANDS
░	A-2-4 A-3	POORLY GRADED CLEAN SANDS
▨	A-2-4 A-4	SAND-SILT MIXTURES
▨	A-2-6 A-6	SAND CLAY MIXTURES
▨	A-4	SILTS OR SILTY SAND
▨	A-6	LEAN CLAYS
▨	A-7-5 A-5	ELASTIC SILTS
▩	A-7-6	FAT CLAYS
▨		ORGANIC SILTS OR CLAYS
✓		PEAT OR COAL

FORMATION SYMBOLS

▤	CLAY SHALE
░	SANDSTONE
▤	SILTSTONE
▦	BEDROCK

KEY TO BORING LOGS

(NOT AN ACTUAL LOG)

BRIDGE

Location: Station 520

Type of Structure: Bridge to carry westbound lanes over Berry Creek.

Site: New bridge will be just north of and parallel to the existing U.S. 10 bridge which will carry future eastbound lanes over Berry Creek. Berry Creek is a small meandering stream with surface flows in the spring and early summer runoff periods. Flows during the remainder of the seasons are confined to the subsurface gravelly sands overlying the bedrock formations.

Foundations and embankments will be subjected to scour during runoff periods.

Investigation: Six test borings were made using truck-mounted power-driven continuous augers. Standard penetration tests were made as borings were advanced.

Findings: Silts and silty gravelly sands overlie formation shales and sandstones. Formations are 15 to 27 feet below existing ground. Water was 1.5 to 11 feet below the surface when borings were made.

Overburden soils derived from erosion of nearby sediments are loosely consolidated and erratic in density.

Formation members are firm, slightly weathered and competent to support concentrated loads.

Sulfates are present in the ground water at a concentration of 50 parts per million.

Recommendations: The entire structure should be founded on piles end bearing on the formation. Concrete or steel "H" piles are preferred due to anticipated difficult driving through gravelly soils under dry conditions. Unit stresses for "H" piles should be limited to 9000 psi.

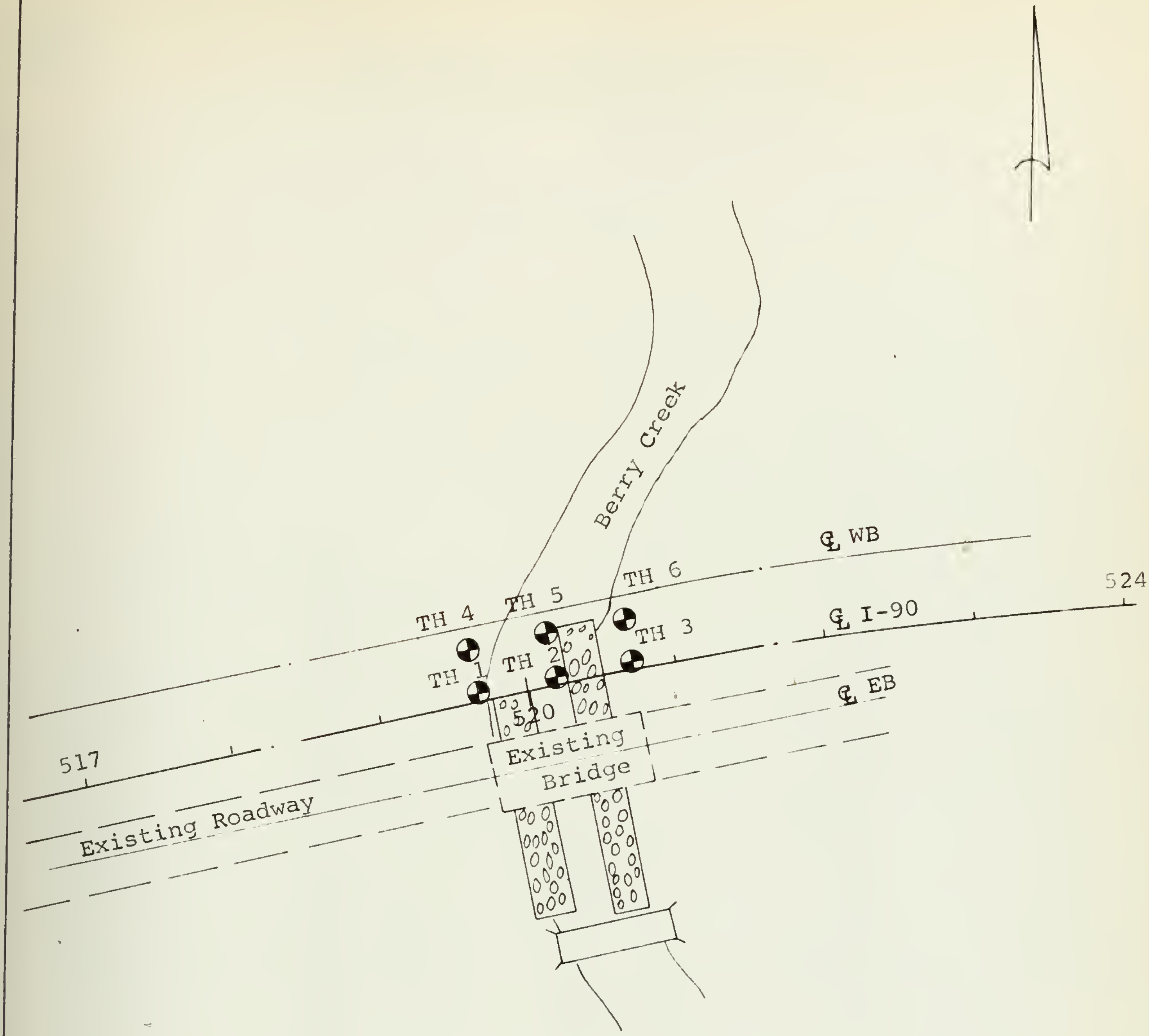
Bearing capacity of 12 inch diameter concrete piles is forty tons.

Channel straightening and embankment rip-rap are recommended. There is an old sandstone quarry about one-half mile north of the site on Pierce Ranch property which is accessible from Craver Road.

Type I cement will be satisfactory for use in concrete exposed to soils or weather.

Estimated Pile Tip Elevations:

		No. Pier	So. Pier
Bent #1	3655		
Bent #2		3655	3653
Bent #3	3655		



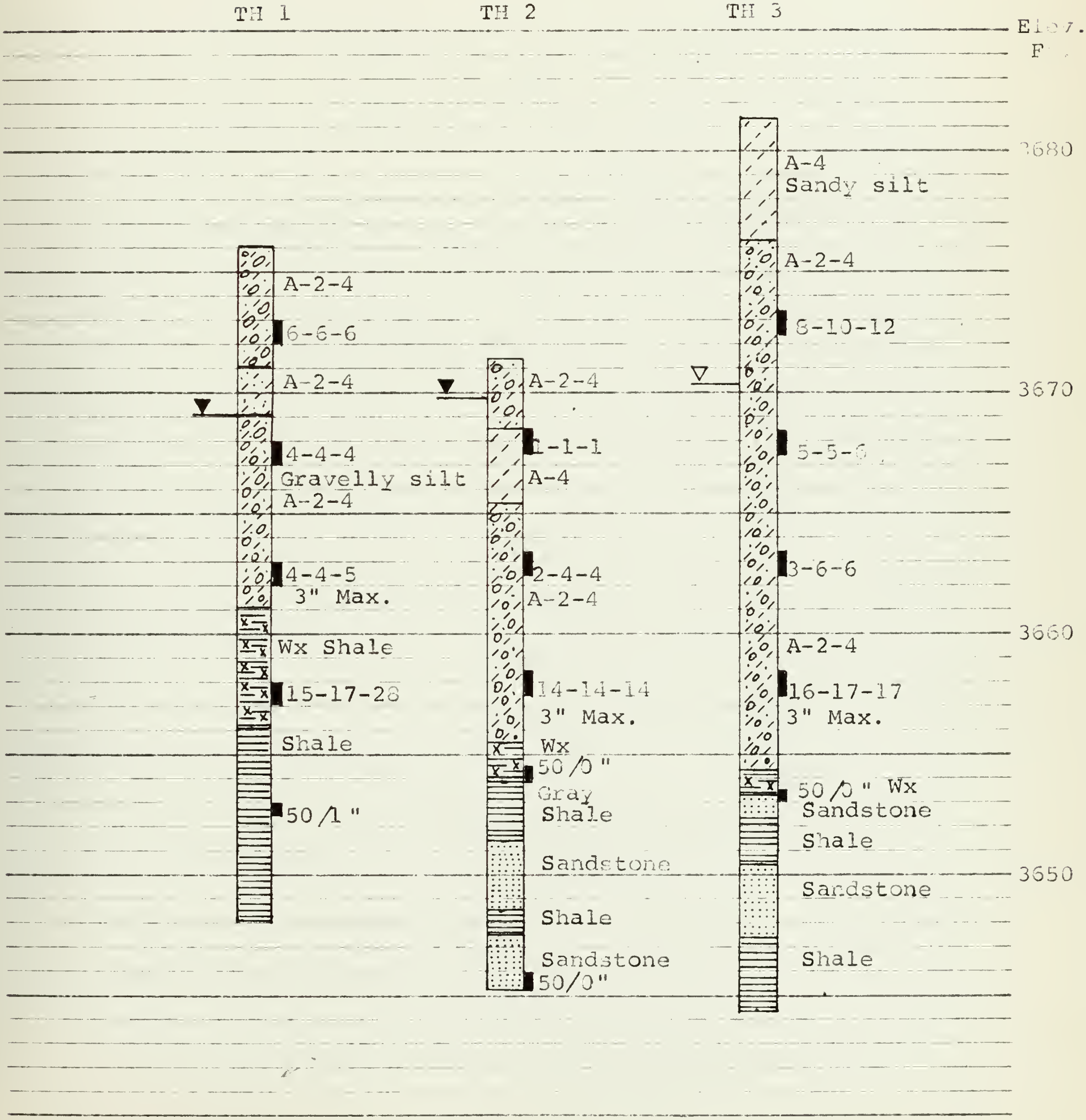
Test Hole Location Plan
Berry Creek Bridge
Station 520+00

Scale 1" = 100'

PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Berry Creek Bridge
Boring Logs



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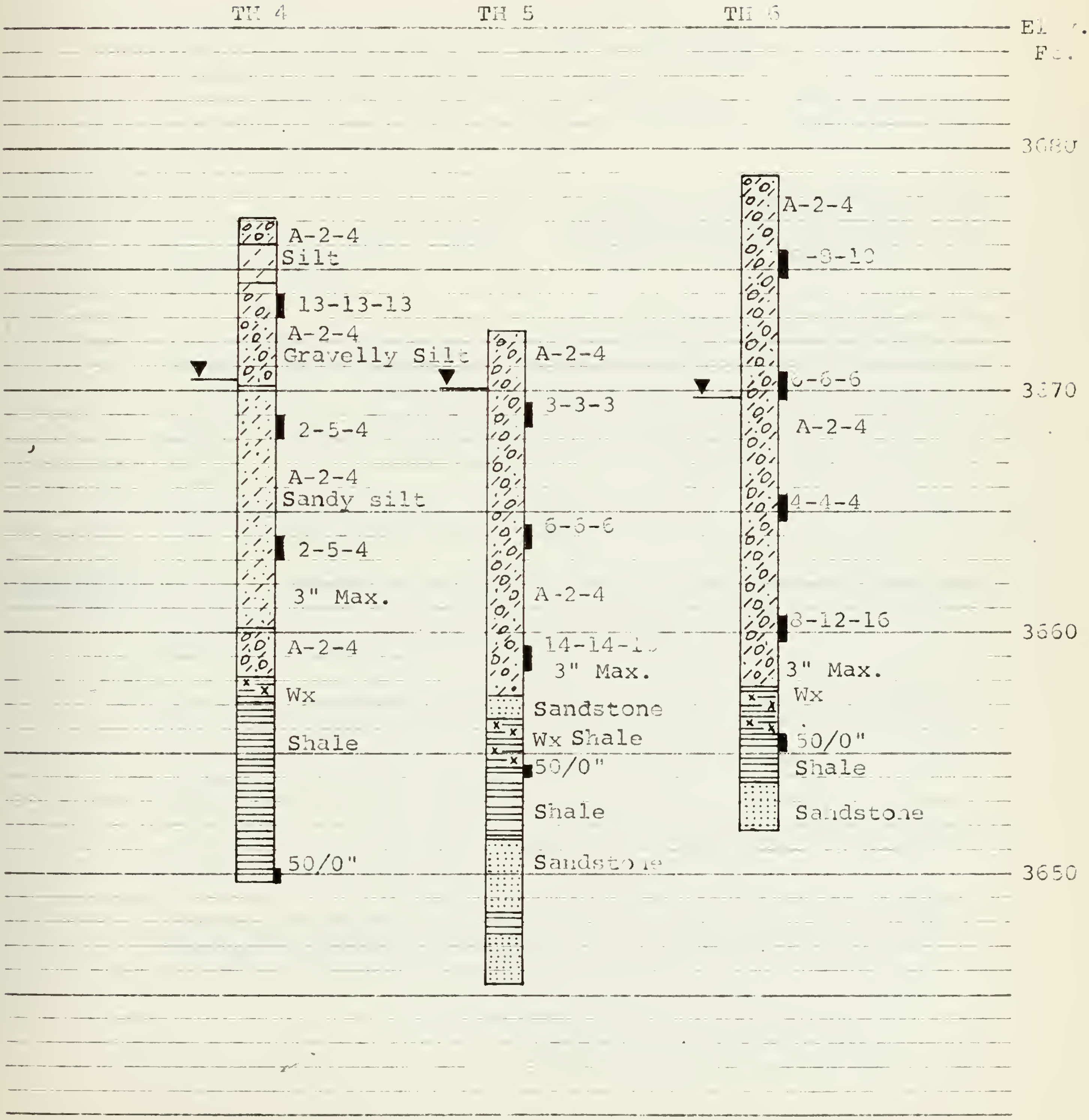
MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Berry Creek Bridge
Boring Logs



BRIDGE

Location: Sta. 534

Type of Structure: Interchange for county road access (Craver Road)

Site: The interchange will be located just north of the intersection of U.S. 10 and the county road. The area is presently occupied by the county road right-of-way, hay meadows, pasture and irrigated farm land. The Merrill-Columbus irrigation ditch passes through the area. The structure will occupy the right-of-way.

Investigation: Five test borings were made using truck-mounted power-driven continuous auger. Standard penetration tests were made of the soils in-place. Samples were secured for laboratory tests.

Findings: Silts and silty-gravelly sands overlie Yellowstone River sandy gravels which are underlain by formation shales and sandstones. Ground water was located at 16-22 feet below the surface. The Yellowstone gravels are 18-23 feet below ground level. Depth to formation varied from 40-56 feet.

Sulfates are present in the ground water at a low concentration of 50 parts per million.

Recommendations: Foundations should be supported by end bearing piles driven into the Yellowstone River gravels. Piles should fetch up immediately in these gravels.

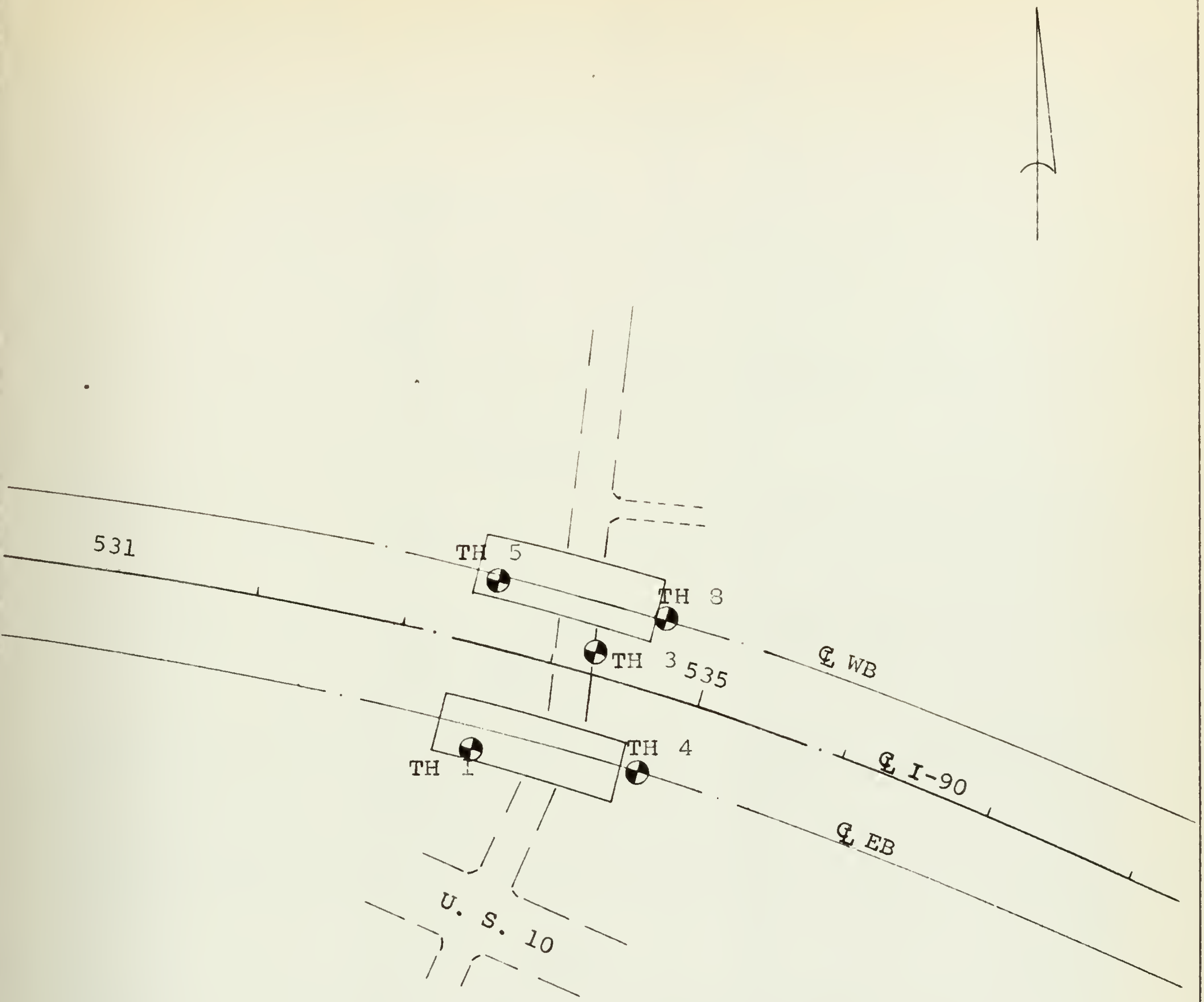
Steel or concrete piles are recommended due to sporadic driving resistance in dry silty soils. Bearing capacity is 9000 psi on steel "H" piles or forty tons on 12 inch diameter concrete piles.

Treated wood piles will require pre-boring through the dry silty gravelly soils.

Type I cement will be satisfactory for use in concrete exposed to soils or weather.

Estimated Pile Tip Elevations:

	Bent 1	Bent 2	Bent 3	Bent 4
East Bound	3652	3650	3650	3650
West Bound	3650	3650	3650	3650

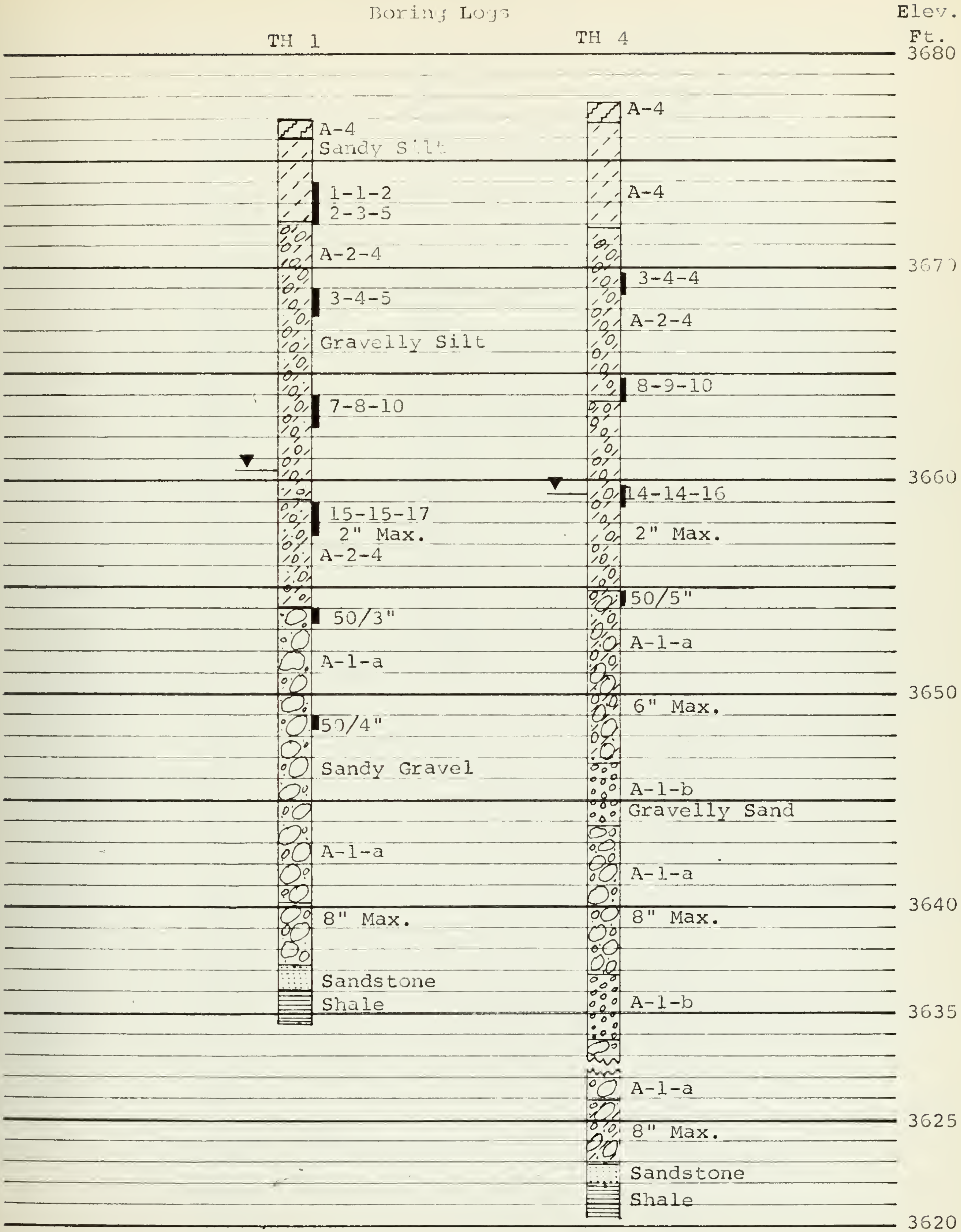


Note: No Test Holes 2,6,7

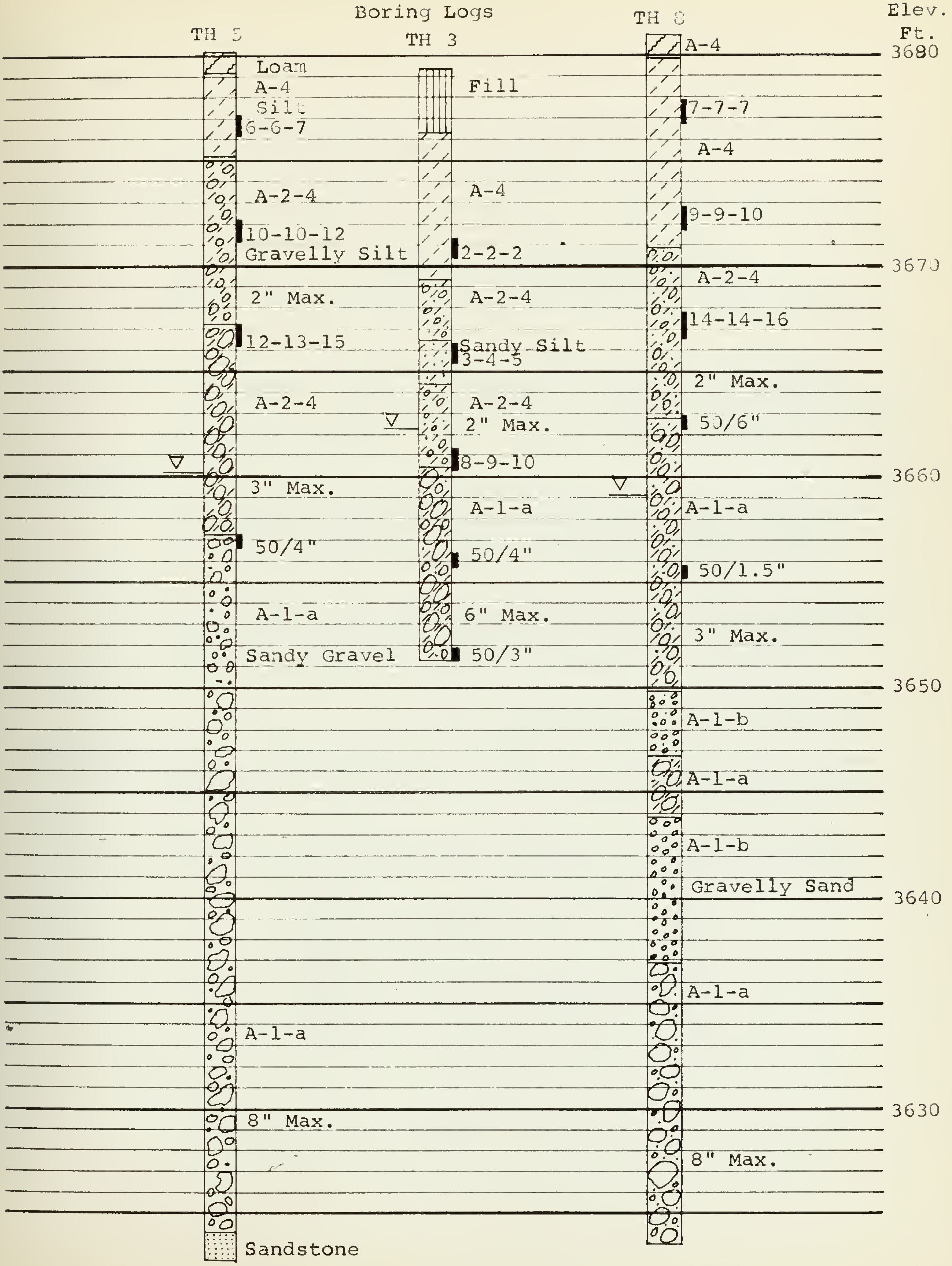
Test Hole Location Plan
Craver Road Interchange
Station 534+00

Scale 1" = 100'

Craver Road Interchange
Boring Logs



Craver Road Interchange
Boring Logs



BRIDGE

Location: Station 894, Rapelje Road Grade Separation.

Type of Structure: Overpass to carry Rapelje Road over Interstate.

Site: Construction will occupy the Rapelje Road right-of-way, pasture land to the west, cultivated farm land to the east. The structure will be primarily in the right-of-way.

Investigation: Seven test borings were made using truck-mounted power-driven continuous auger. Standard penetration tests were made of the soils in-place. Samples were secured for laboratory tests.

Findings: Silts and gravelly sands of erratic density overlie formation shales and sandstones found at depths ranging from 1-23 feet below the surface. The top of the buried formation slopes downward from north to south.

Ground water was present in the formation 20.5 feet below the ground surface. Sulfates were present in the ground water at a concentration of 100 parts per million.

The formation shales and sandstones are suitable bearing.

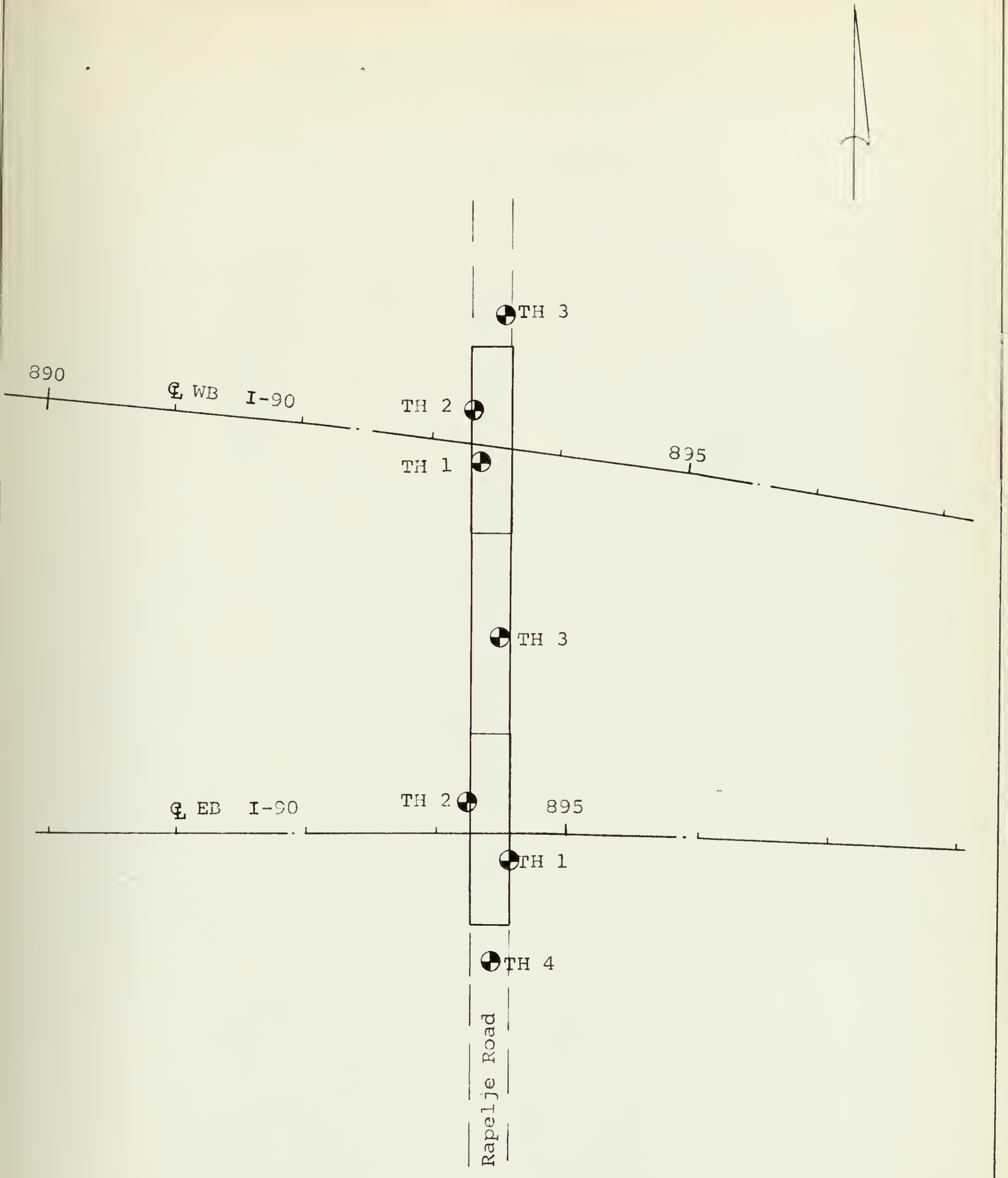
Recommendations: Bents should be founded on spread footings and/or piles bearing on the formation members according to this schedule:

Bent No.	Foundation Type	Estimated Bearing Elevation
1	Piles	Pile Tip 3680
2	Spread footings	3680
3	Spread footings	3678
4	Piles	Pile Tip 3665
5	Piles	Pile Tip 3660
6	Piles	Pile Tip 3660
7	Piles	Pile Tip 3660

Footings should penetrate the formation a minimum distance of one foot and should be designed to exert a minimum soil pressure of 4 ksf and a maximum of 10 ksf.

Steel "H" end bearing piles are recommended. Unit stresses for these piles should not exceed 9000 psi.

Type I cement will be suitable for use in concrete exposed to soils or weather.

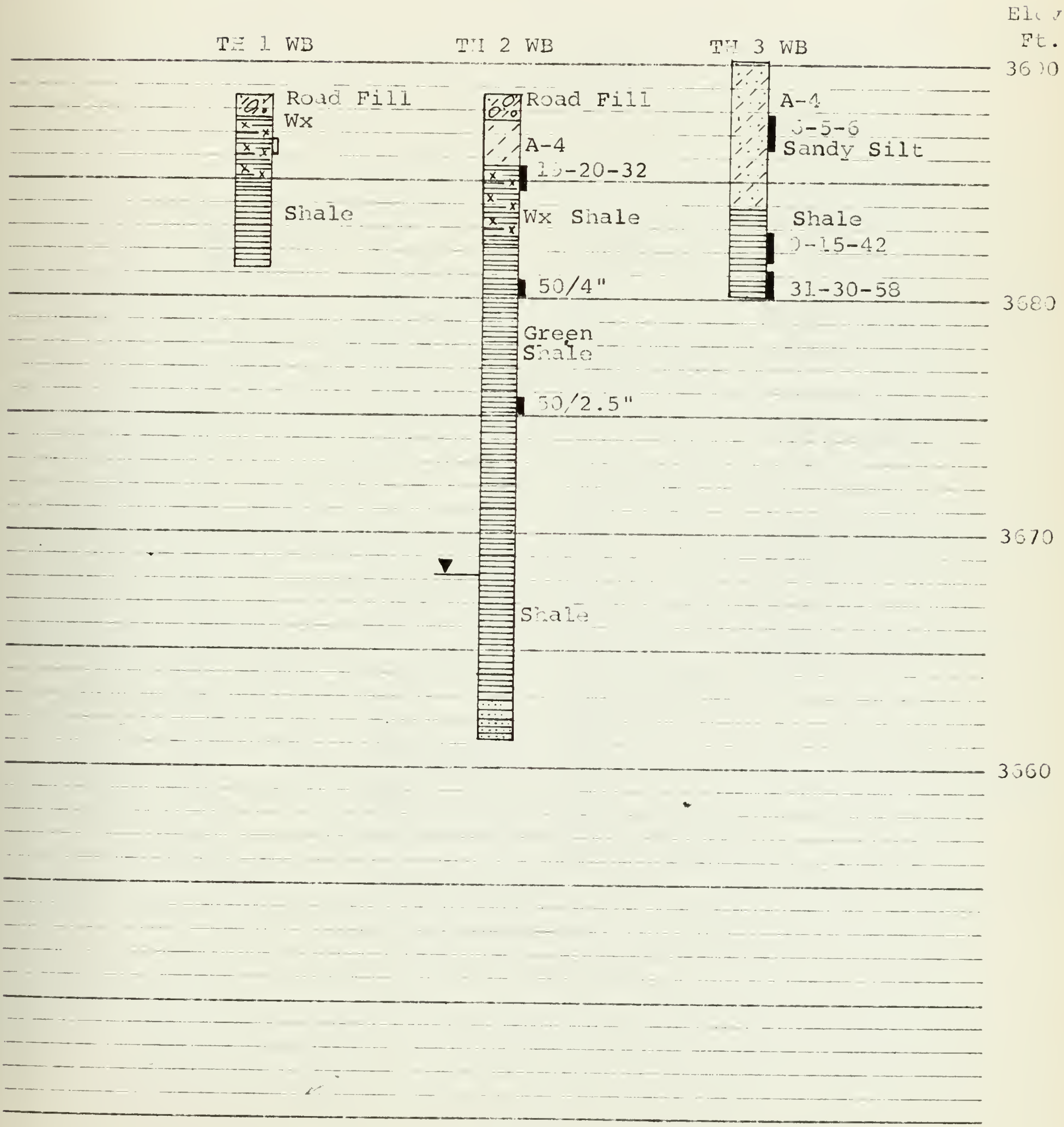


Test Hole Location Plan
Rapelje Road Grade Separation
Sta. 893+52 WB
Sta. 894+39 EB
Scale 1" = 100'

PHONE 534 5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

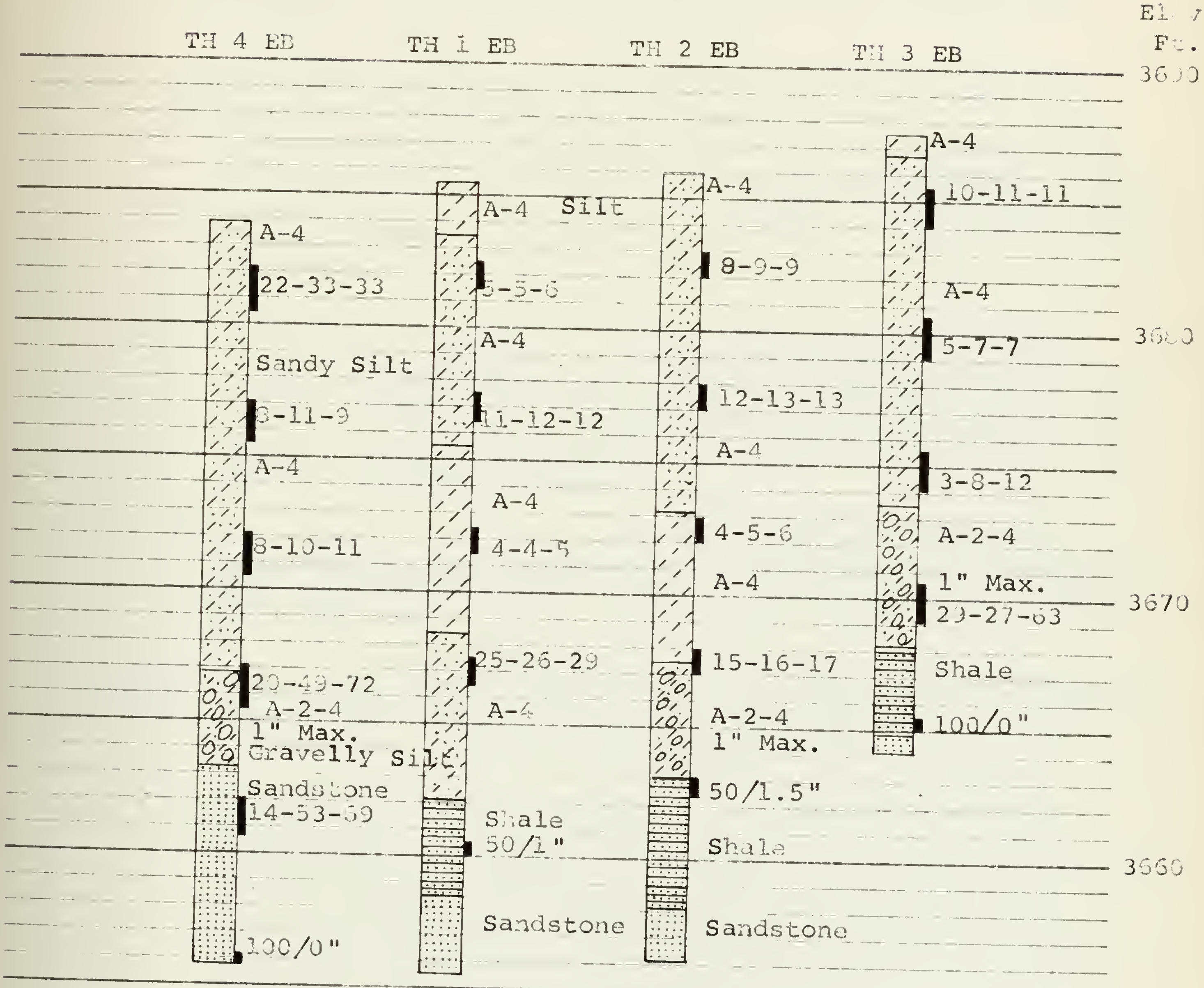
Rapelje Road Grade Separation
Boring Logs



PHONE 534 5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

Rapelje Road Grade Separation
Boring Logs



All four holes dry

BRIDGE

Location: Station 916

Type of Structure: Two three-span bridges to carry eastbound and westbound lanes over Keyser Creek.

Site: Keyser Creek occupies a prominent drainage with year round surface flow and appreciable seasonal runoff. The creek bottom is brush and timbered pasture. Approaches on the west side of the creek will be on irrigated farmland which is bordered on the south by the Columbus Water Users Association irrigation ditch. The east side is poorly cultivated farmland.

A hillside rises to an outcrop just east of the bridge site, soil overburden on the hillside is shallow, the formation exposed by the outcrop is thin-bedded sandstone. Keyser Creek passes through the central portion, on the west side there is an alluvial terrace eight or nine feet above the channel bottom.

Investigation: Eleven test borings were made using truck-mounted power-driven continuous auger. Standard penetration tests were made of the soils in-place and samples were secured for laboratory tests.

Findings: Silts and gravelly, silty sands overlie formation sandstones and shales. Depth to formation ranged from 16-38 feet. Ground water was 5-20 feet below surface.

There is evidence that Keyser Creek scours its channel frequently. Alluvium deposited in the streambed and terrace contains chunks of sandstone up to one foot across which have not travelled very far judging from their angular appearance. Rocky material is interbedded with very fine sand and silt. The latter tends to be loose according to Standard Penetration blow counts but the rocky material is more dense. Water tables are controlled by the level of Keyser Creek and stood about elevation 3622 when drilled.

Bedrock surface beneath the site has been eroded into a scoop shape with the mouth pointing downstream and a flat surface adjoining the western edge of the scoop. Bedrock consists of hard, gray-green silty shale, interbedded with sandstone and is competent.

Sulfates are present in the ground water at a concentration of 50 parts per million.

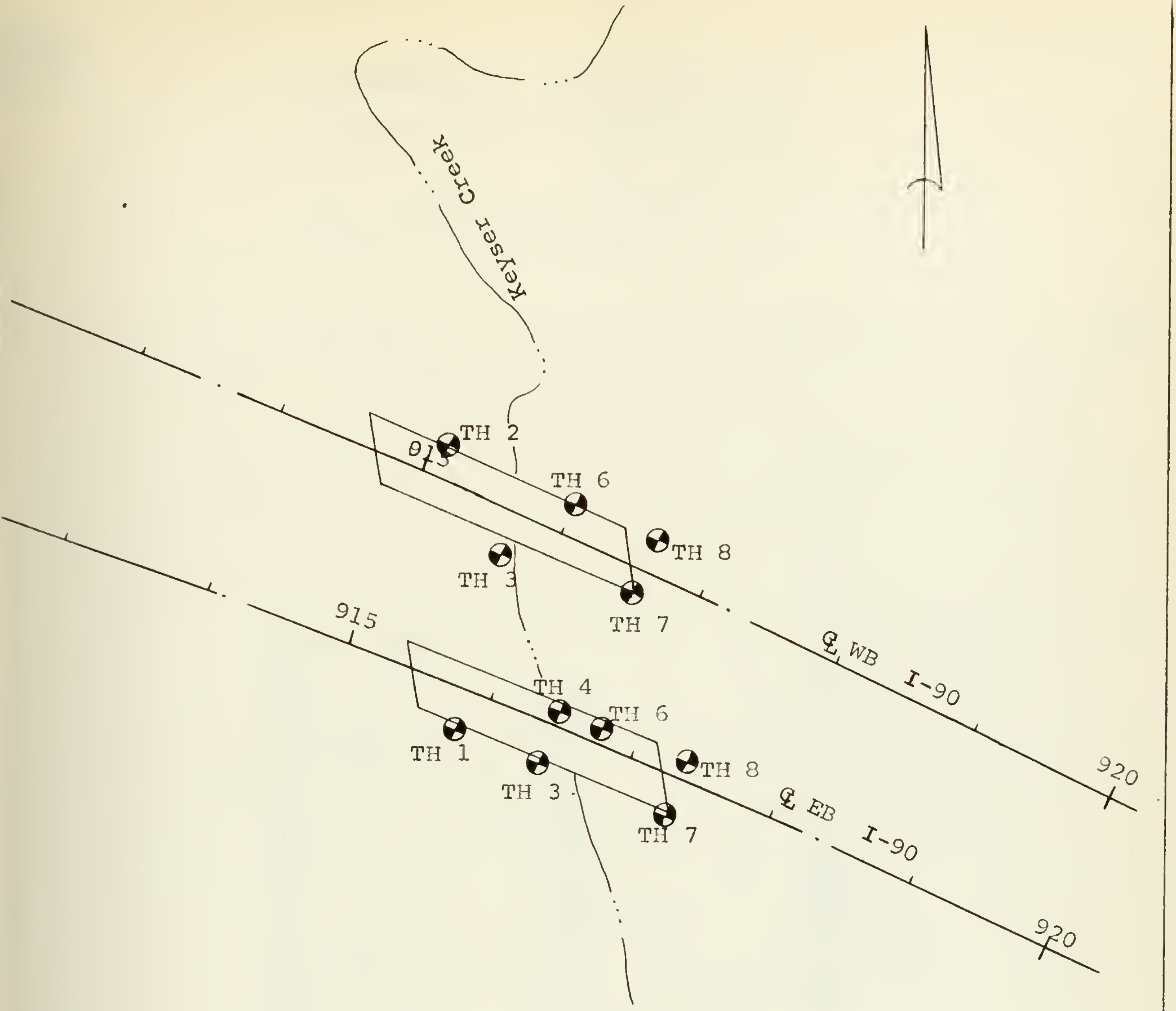
Recommendations: It is recommended that foundations for all bents be placed on steel "H" piles driven to bearing on the sandstone and shale formation. Design piles for a maximum unit stress of 9000 psi on the cross-sectional area.

Type I cement will be suitable for use on concrete exposed to soils or weather.

Estimated Pile Tip Elevations:

	Bent 1	Bent 2	Bent 3	Bent 4
Eastbound	3605	3598-3600*	3606-3608*	3613-3618*
Westbound	3605	3605	3605-3610	3620

* Tip elevation rises to the north



Note: No Test Holes 1,4,5 WB
or Test Holes 2,5,EB

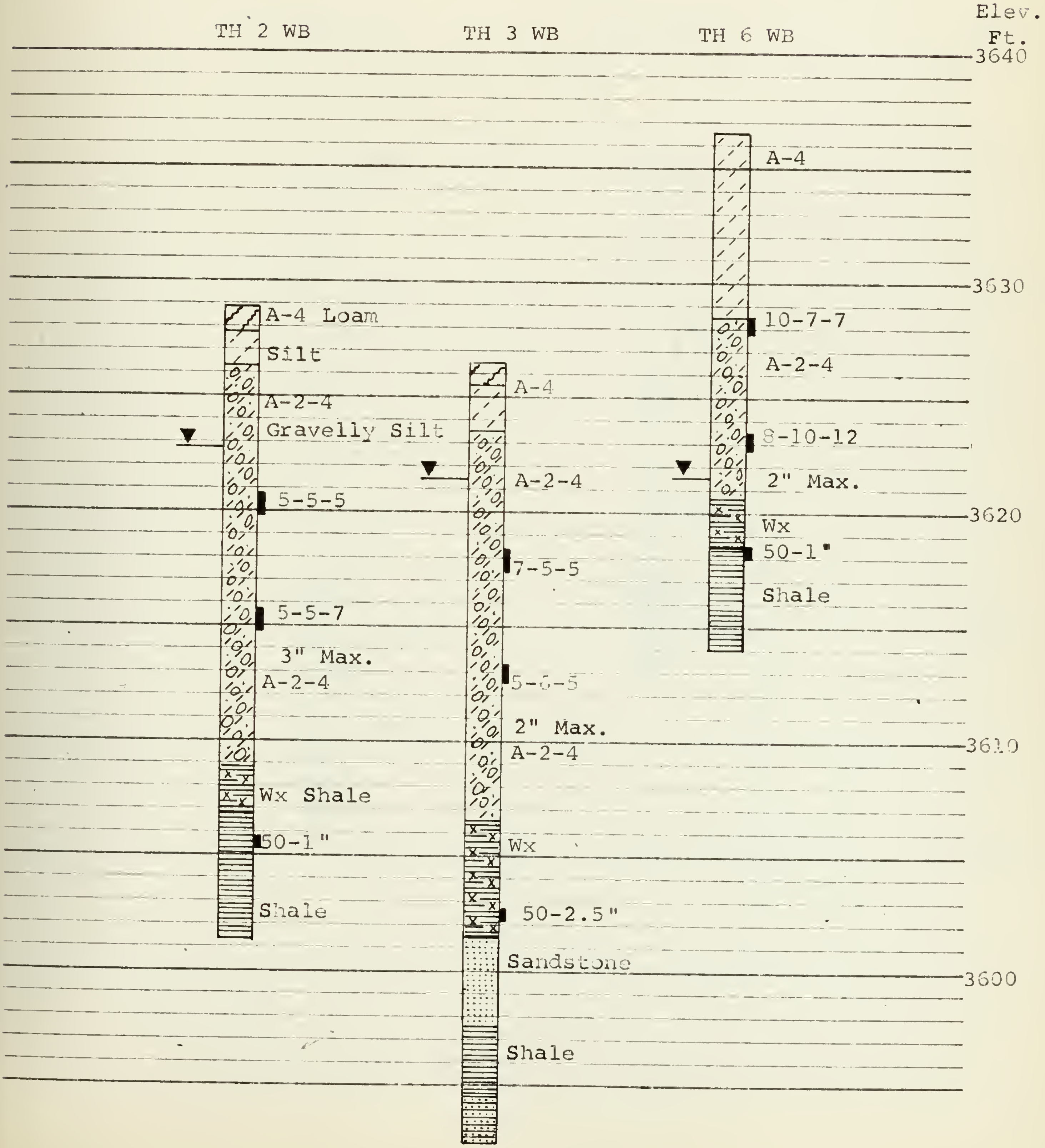
Test Hole Location Plan
Keyser Creek Bridge
Station 915+

Scale 1" = 100'

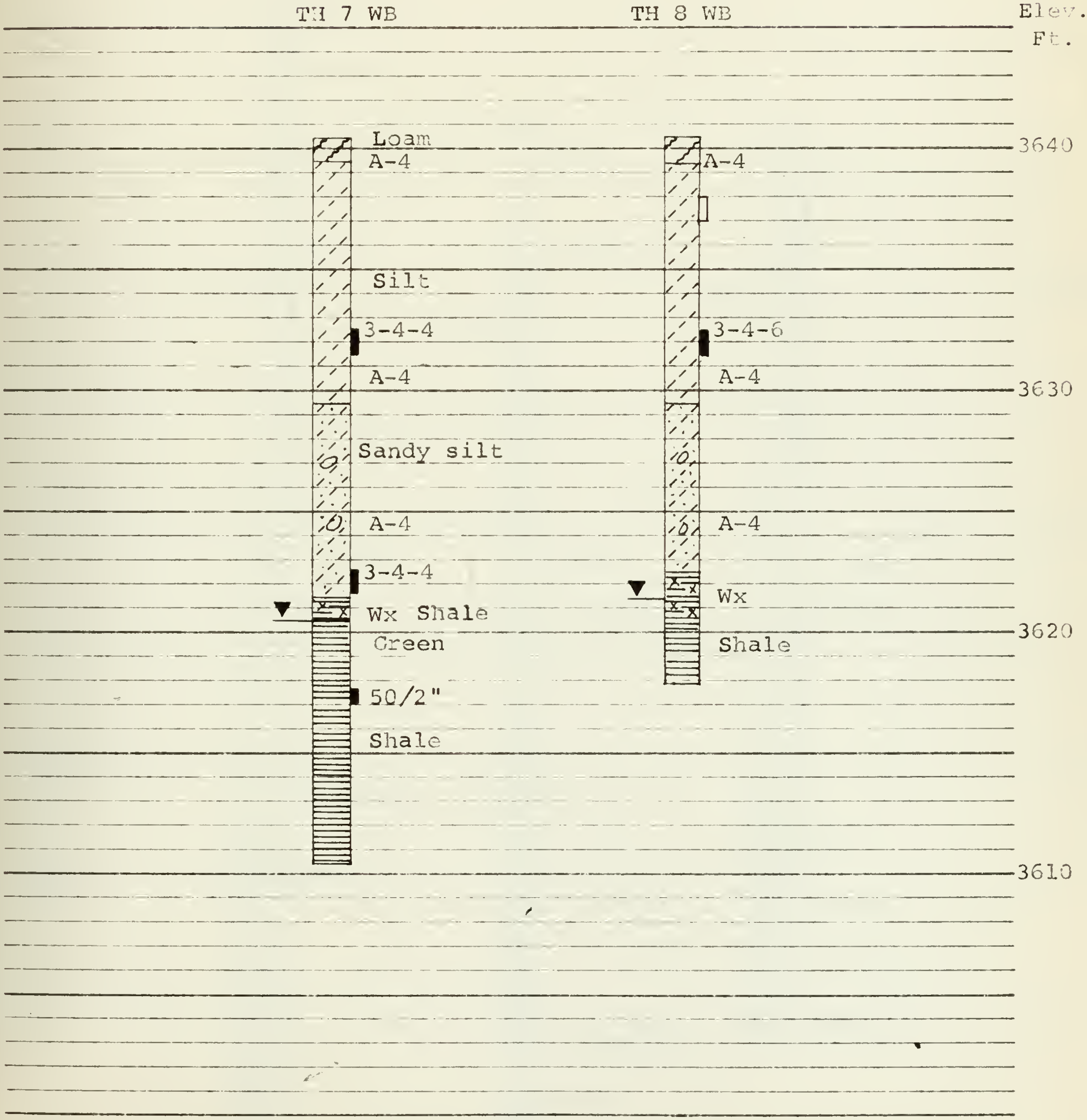
PHONE 534-5331

MATERIALS & SUBSTRUCTURES
CONSULTING ENGINEERS
540 WEST ELK PLACE DENVER, COLORADO 80216

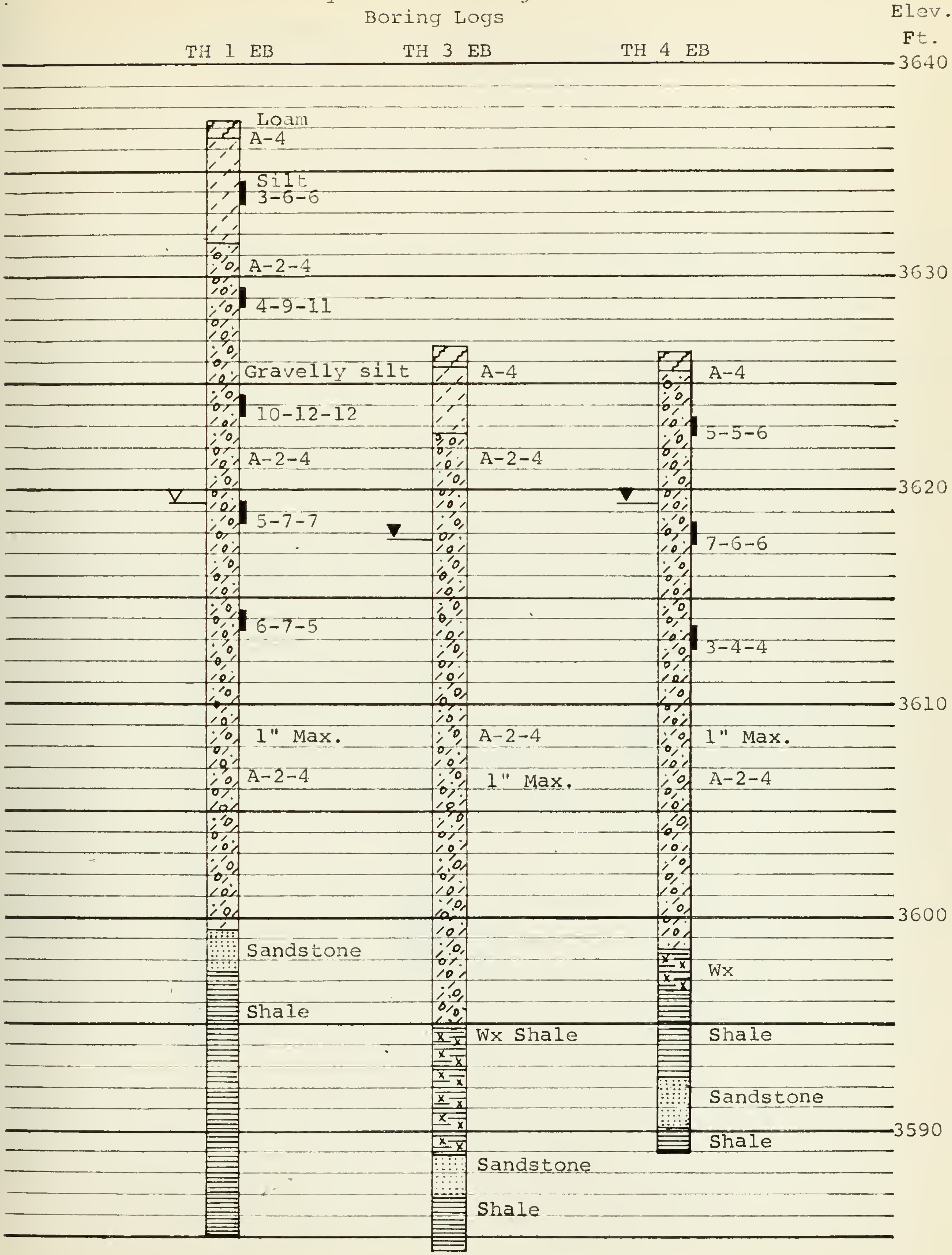
Keyser Creek Bridge
Boring Logs



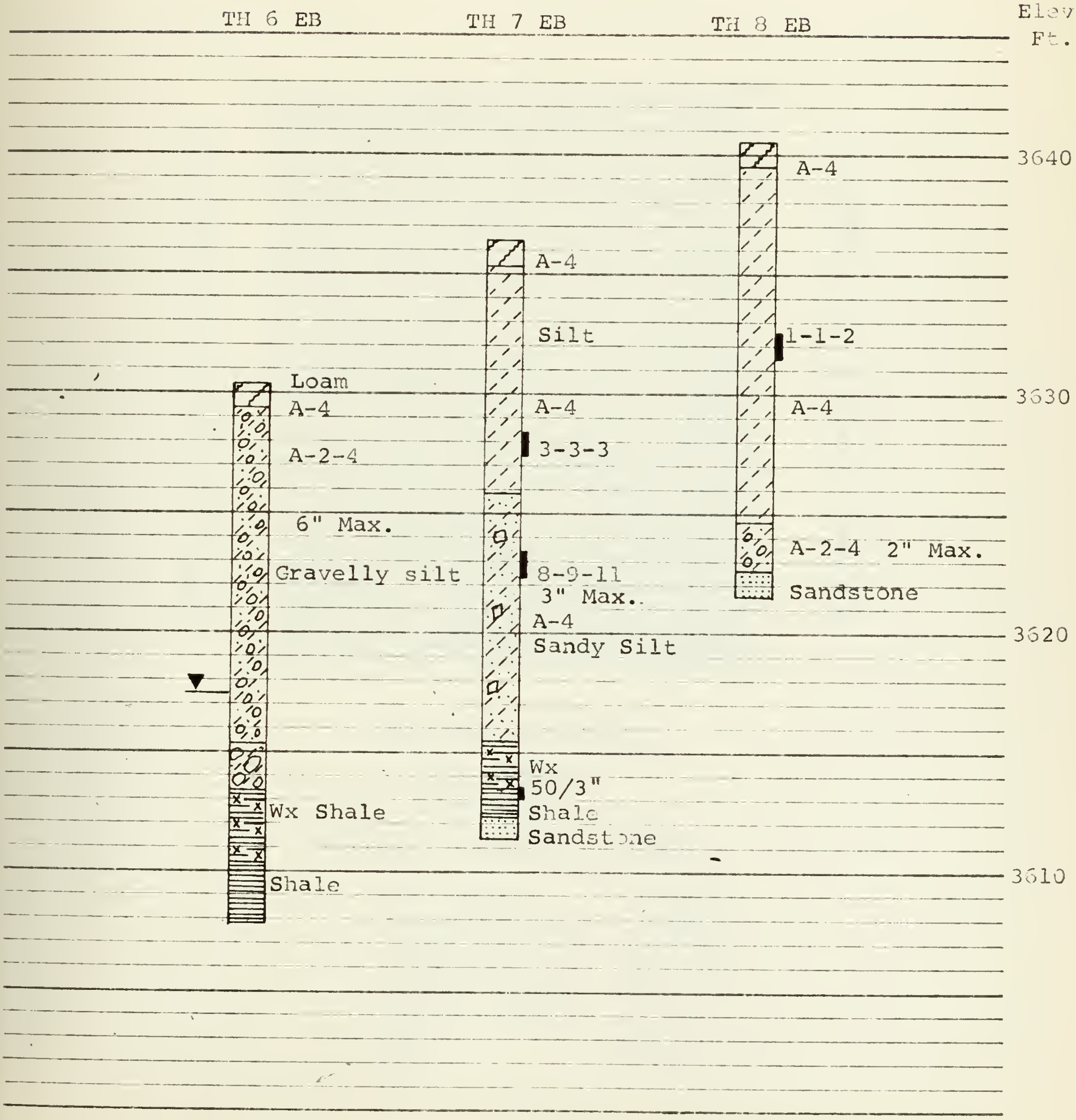
Keyser Creek Bridge
Boring Logs

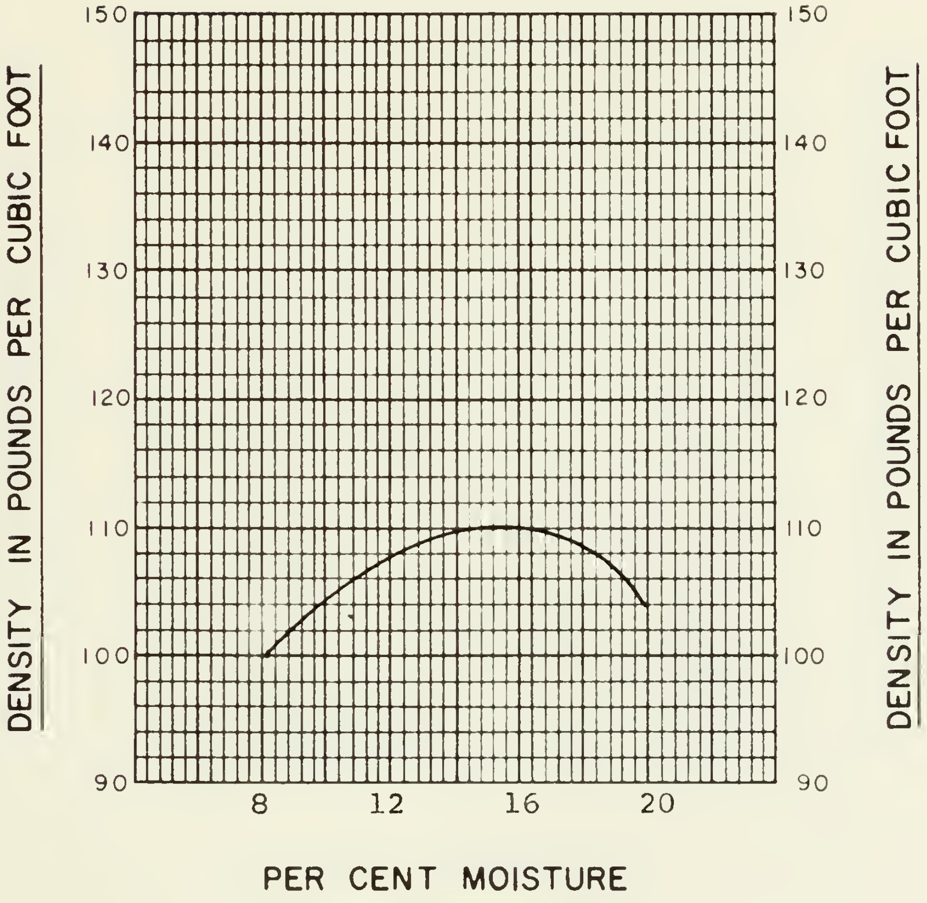


Keyser Creek Bridge
Boring Logs



Keyser Creek Bridge
Boring Logs

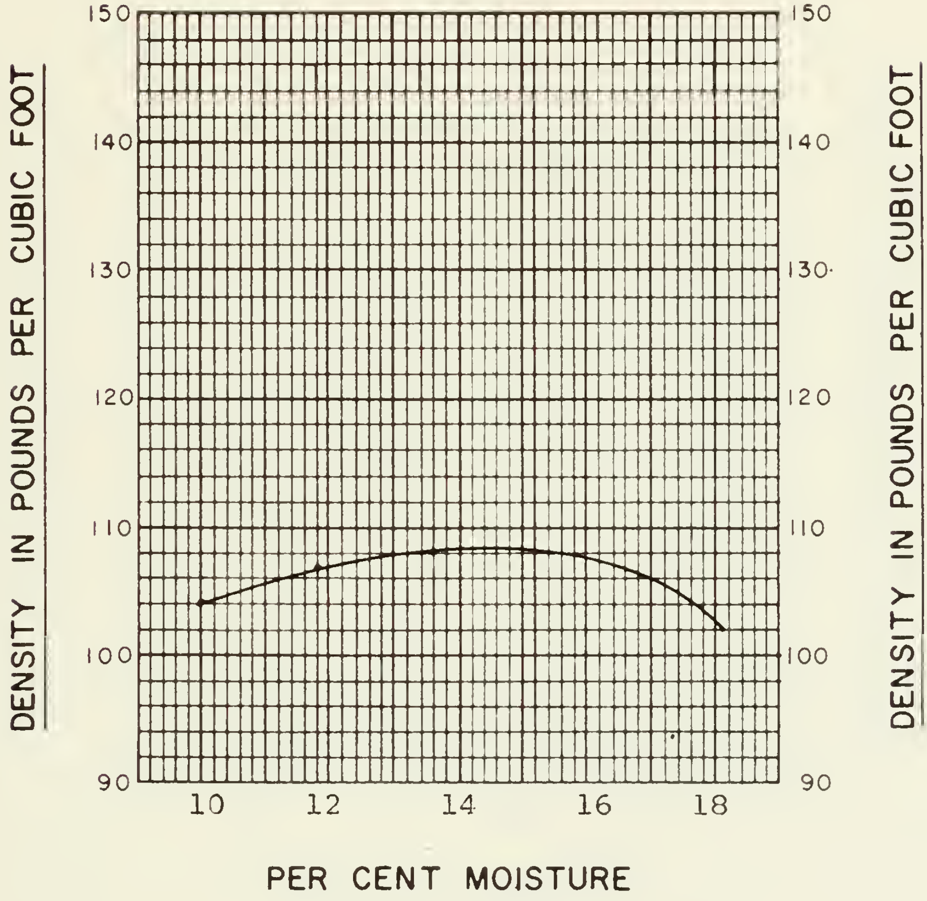




Sta. 586+00
Silt A-4(8)

MOISTURE — DENSITY CURVE

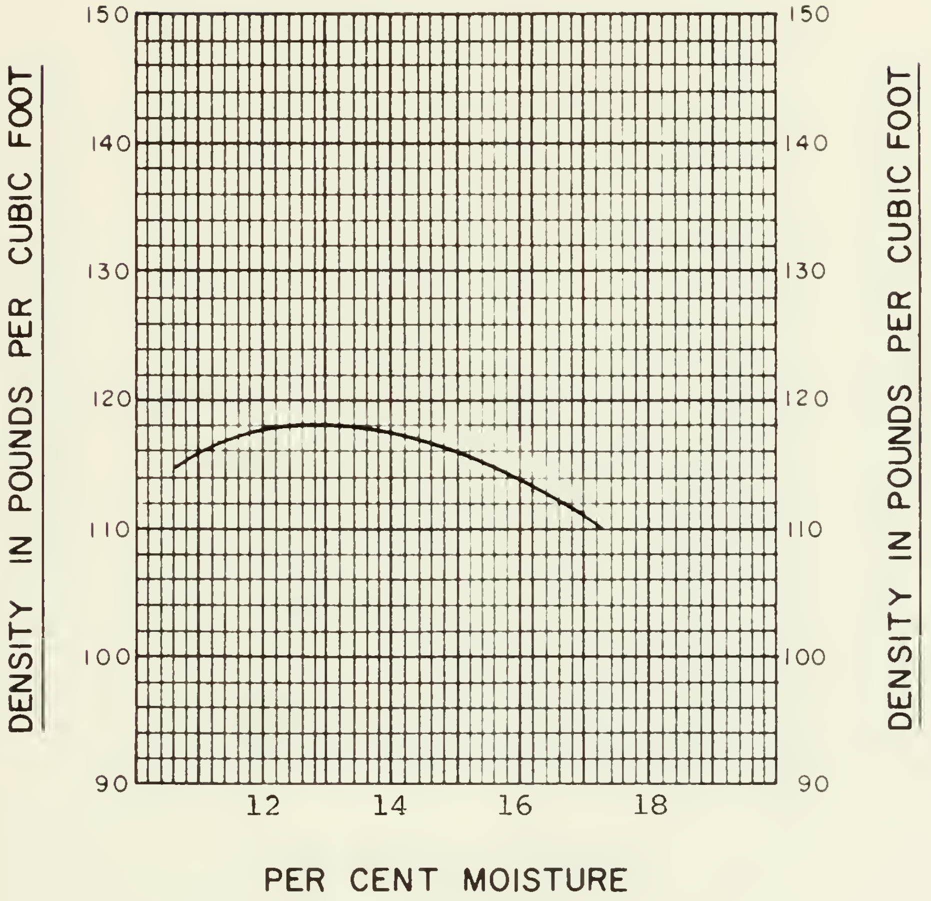
TEST METHOD	T-99-A
OPTIMUM MOISTURE	15.8%
MAXIMUM DRY DENSITY	110 PCF
Liquid Limit	23
Plast. Index	2
#4	100
#200	75



Sta. 677+50
Silty Fine Sand A-4(4)

MOISTURE — DENSITY CURVE

TEST METHOD	T-99-A
OPTIMUM MOISTURE	14.5%
MAXIMUM DRY DENSITY	109 PCF
Liquid Limit	NP
Plast. Index	NP
#4	100
#200	53

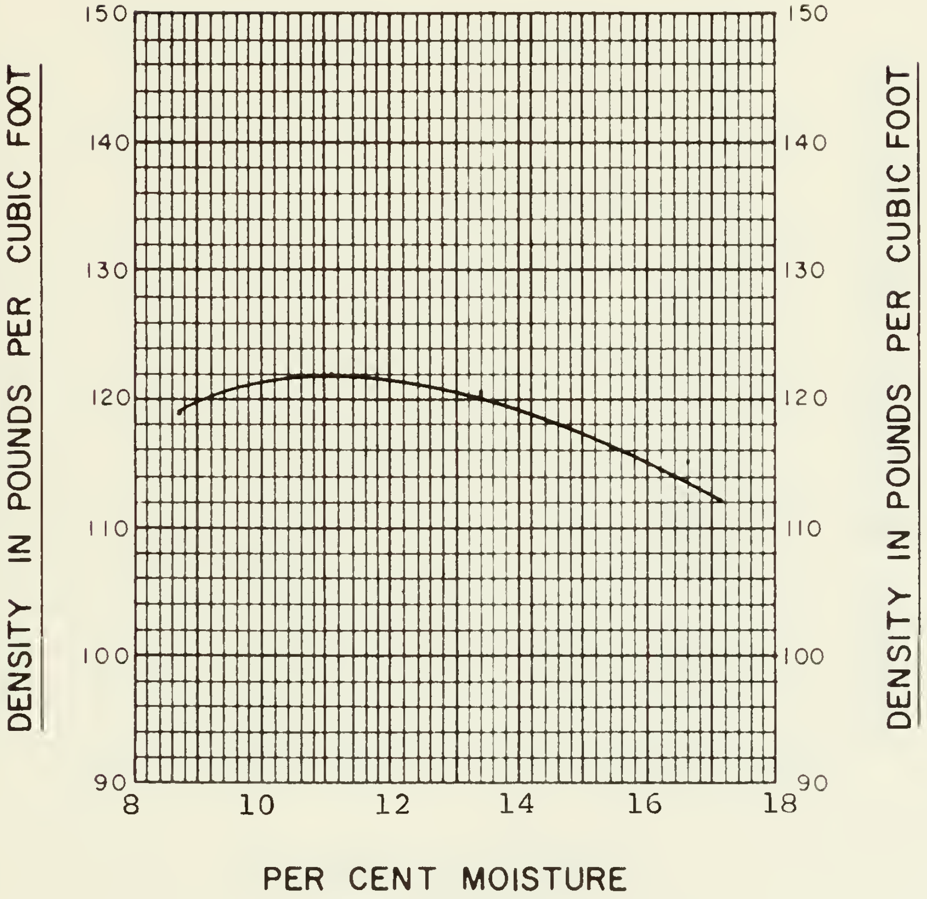


Sta. 735+00

Weathered Shale A-6(2)

MOISTURE — DENSITY CURVE

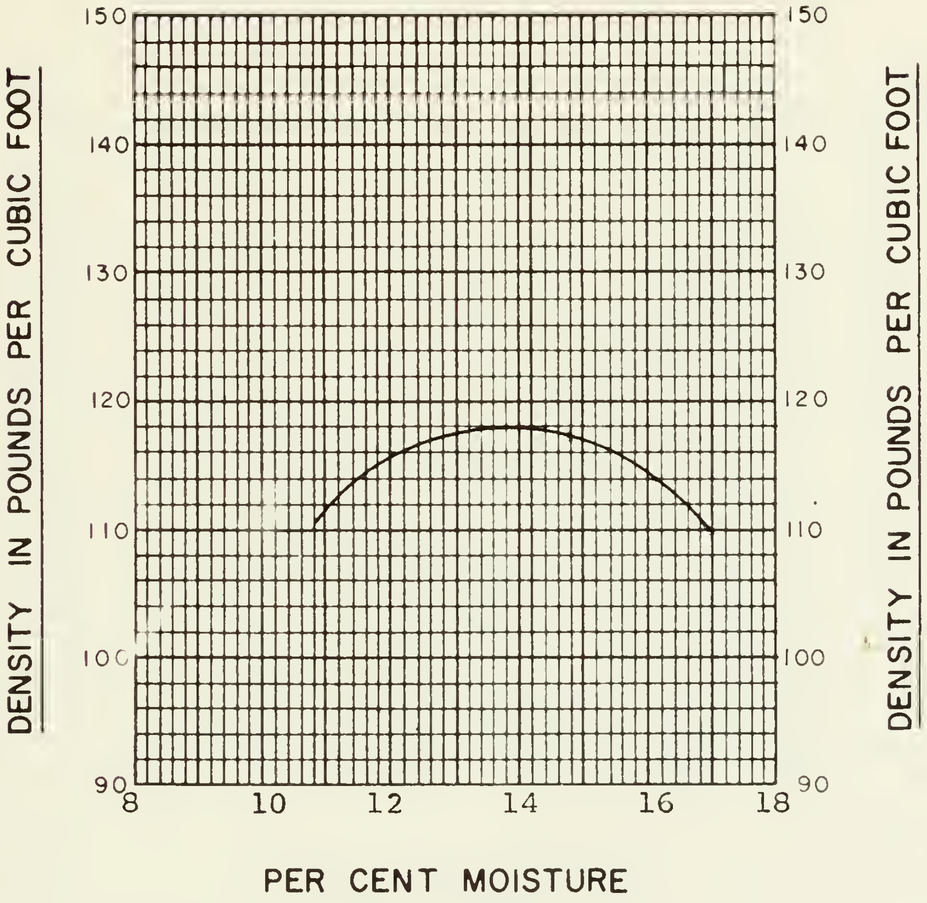
TEST METHOD	T-99-A
OPTIMUM MOISTURE	13.2%
MAXIMUM DRY DENSITY	118 PCF
Liquid Limit	27
Plast. Index	11
#4	68
#200	43



Sta. 758+00
Light Green Shale A-4

MOISTURE — DENSITY CURVE

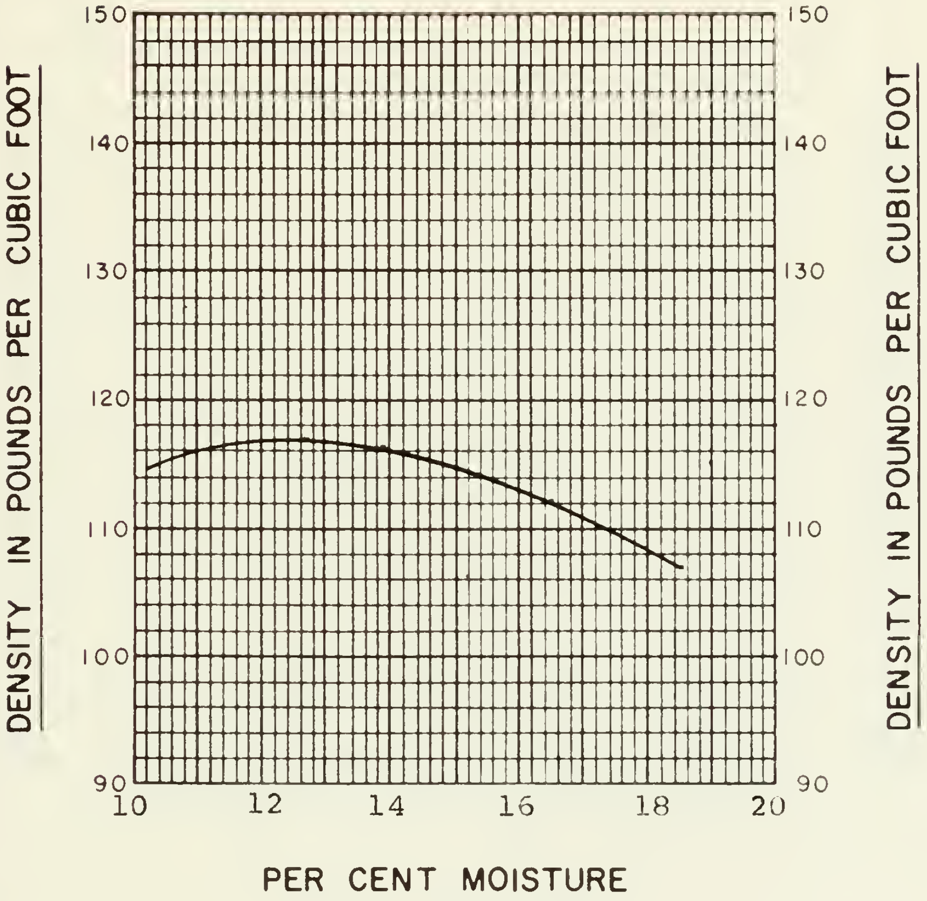
TEST METHOD	T-99-A
OPTIMUM MOISTURE	11.4%
MAXIMUM DRY DENSITY	122 PCF
Liquid Limit	28
Plast. Index	8
#4	91
#200	70



Sta. 818+50
Weathered Green Shale A-6(8)

MOISTURE — DENSITY CURVE

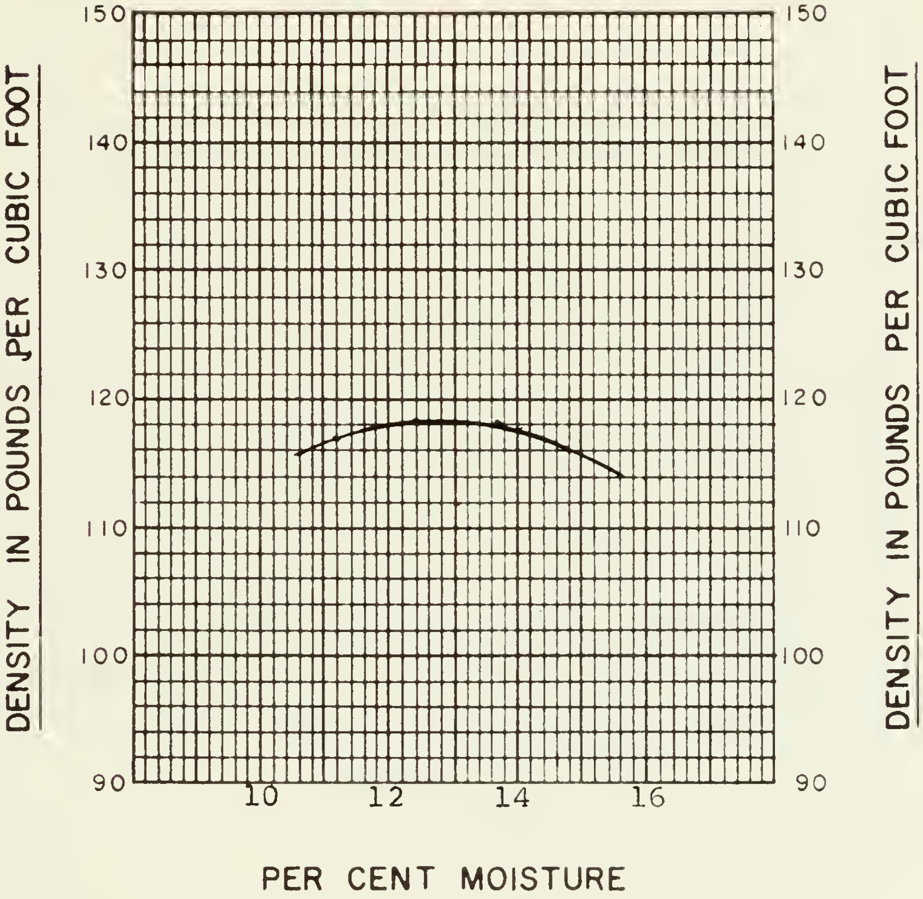
TEST METHOD	T-99-A
OPTIMUM MOISTURE ..	14.0%
MAXIMUM DRY DENSITY	118 PCF
Liquid Limit	26
Plast. Index	11
#4	83
#200	70



Sta. 885+00
Silt A-4(8)

MOISTURE — DENSITY CURVE

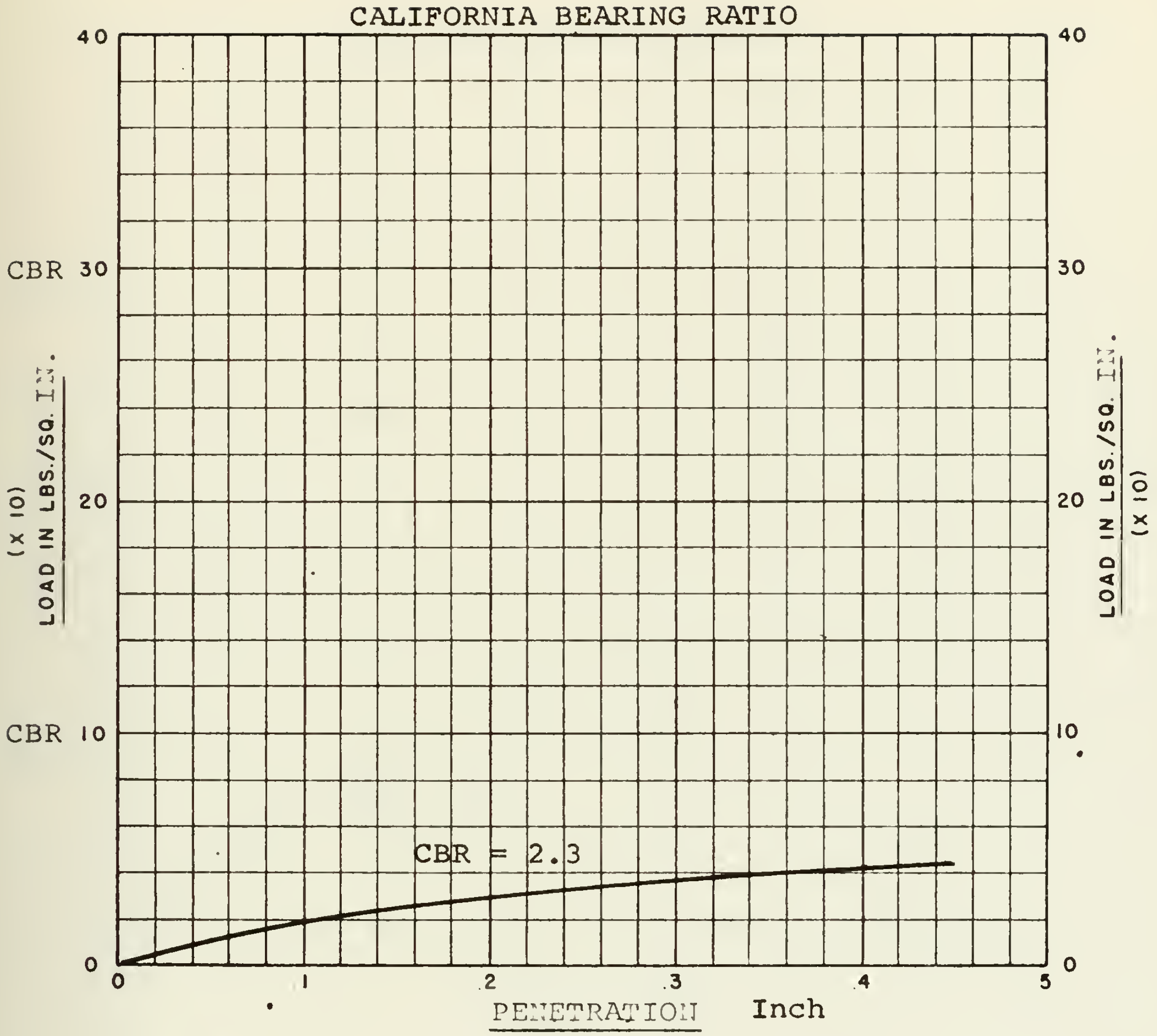
TEST METHOD	T-99-A
OPTIMUM MOISTURE	12.5%
MAXIMUM DRY DENSITY	117 PCF
Liquid Limit	25.0
Plast. Index	6
#4	97
#200	74



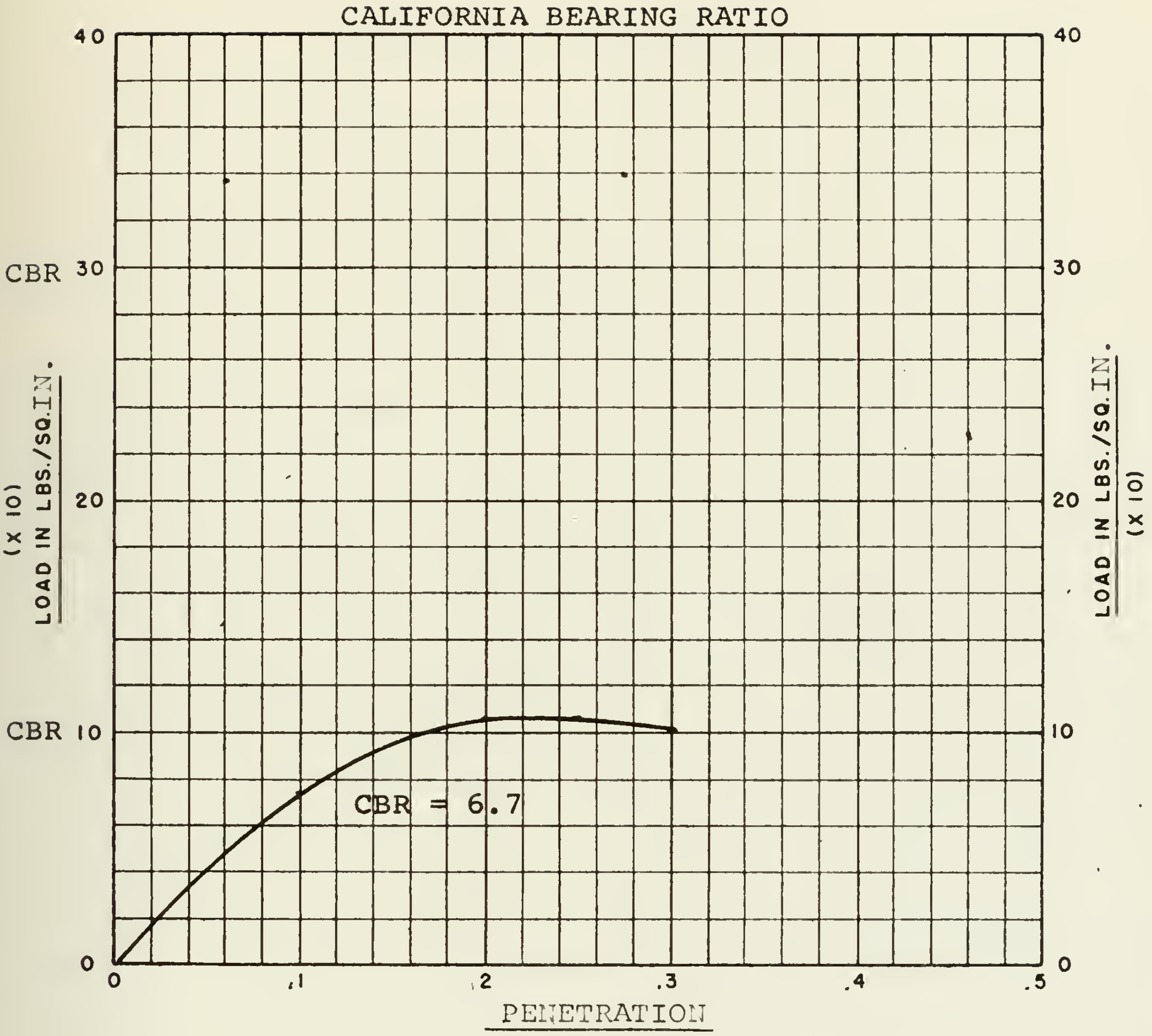
Sta. 923+00
Weathered Siltstone A-4(8)

MOISTURE — DENSITY CURVE

TEST METHOD	T-99-A
OPTIMUM MOISTURE	13%
MAXIMUM DRY DENSITY	118 PCF
Liquid Limit	NP
Plast. Index	NP
#4	100
#200	82

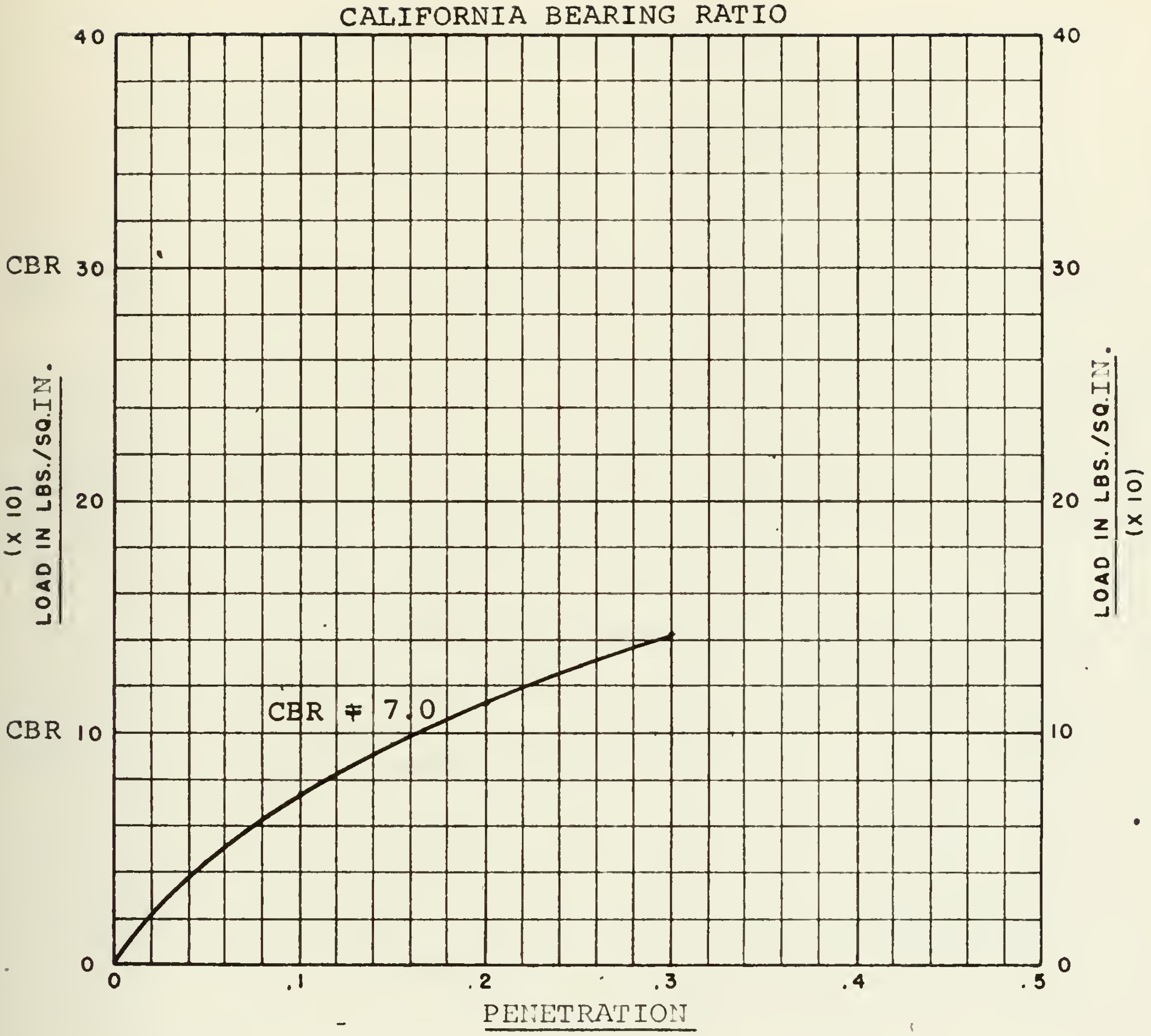


STATION 586+00
TEST PIT #4
SOIL TYPE Silt A-4(8)
MOISTURE INITIAL 12.2%
MOISTURE FINAL 21.3%
NATURAL DRY DENSITY 102 PCF

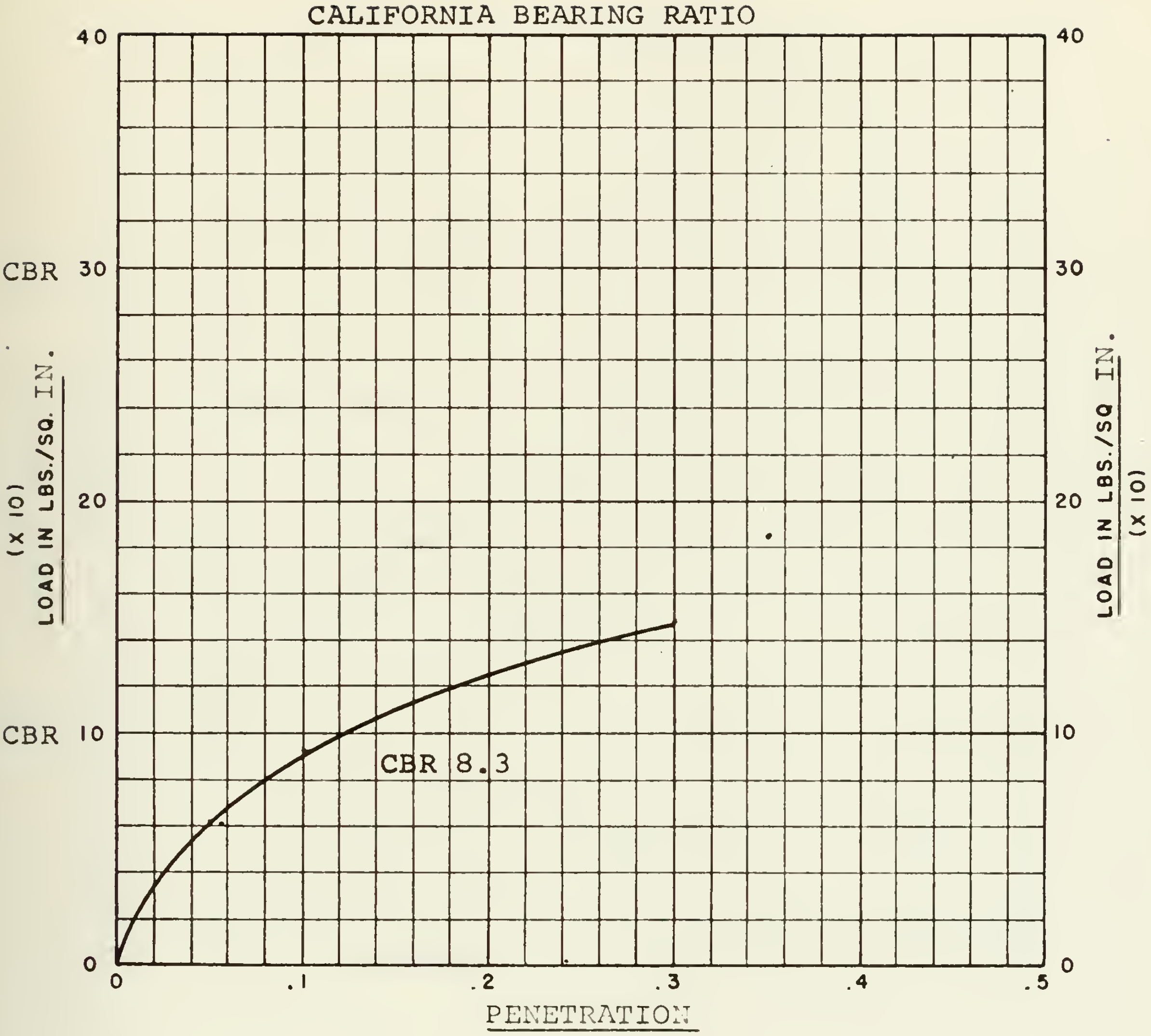


STATION 677+50
TEST PIT #6

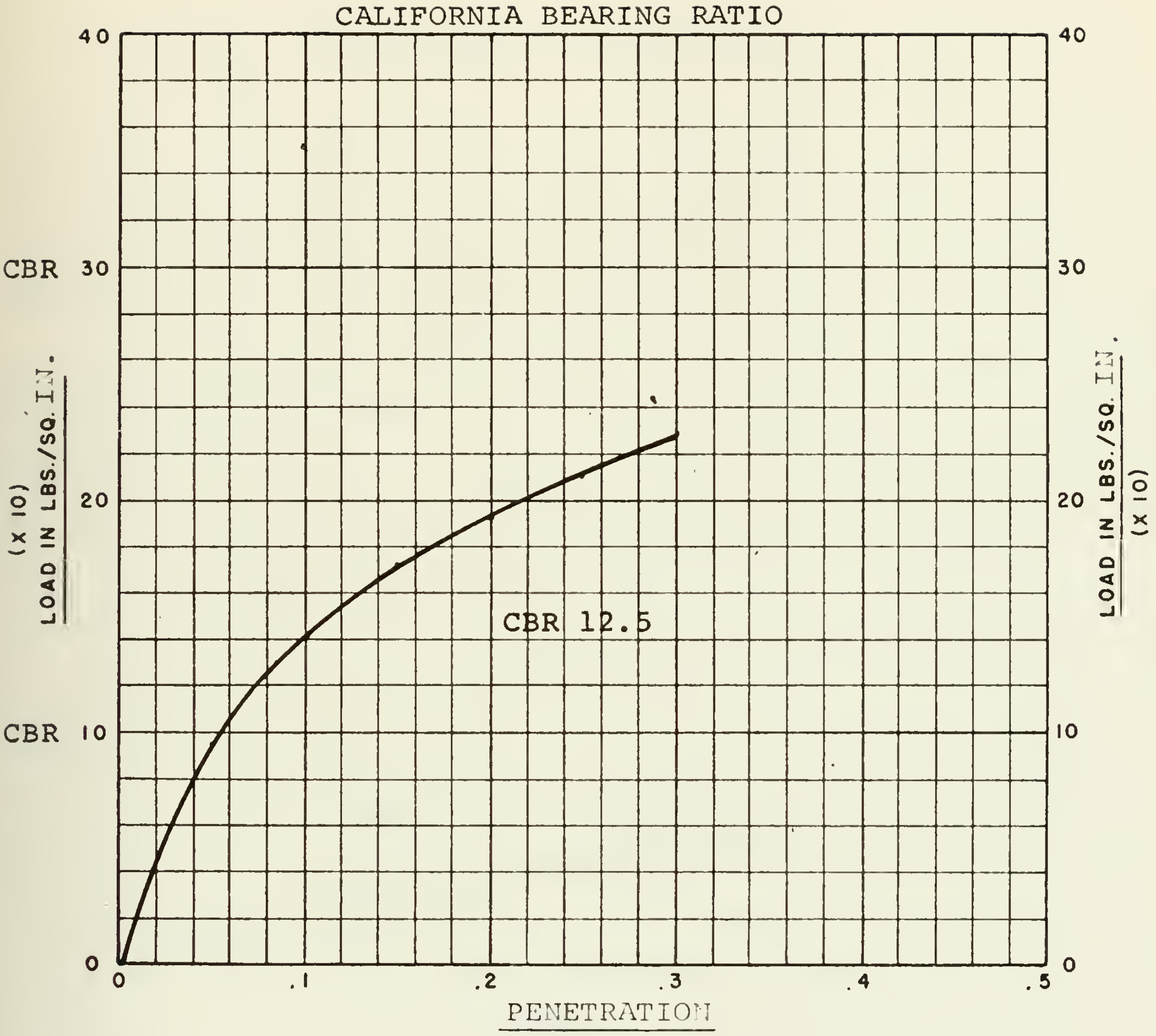
SOIL TYPE	Silty Fine Sand A-4(4)
MOISTURE INITIAL	13.5%
MOISTURE FINAL	16.6%
NATURAL DRY DENSITY	108 PCF



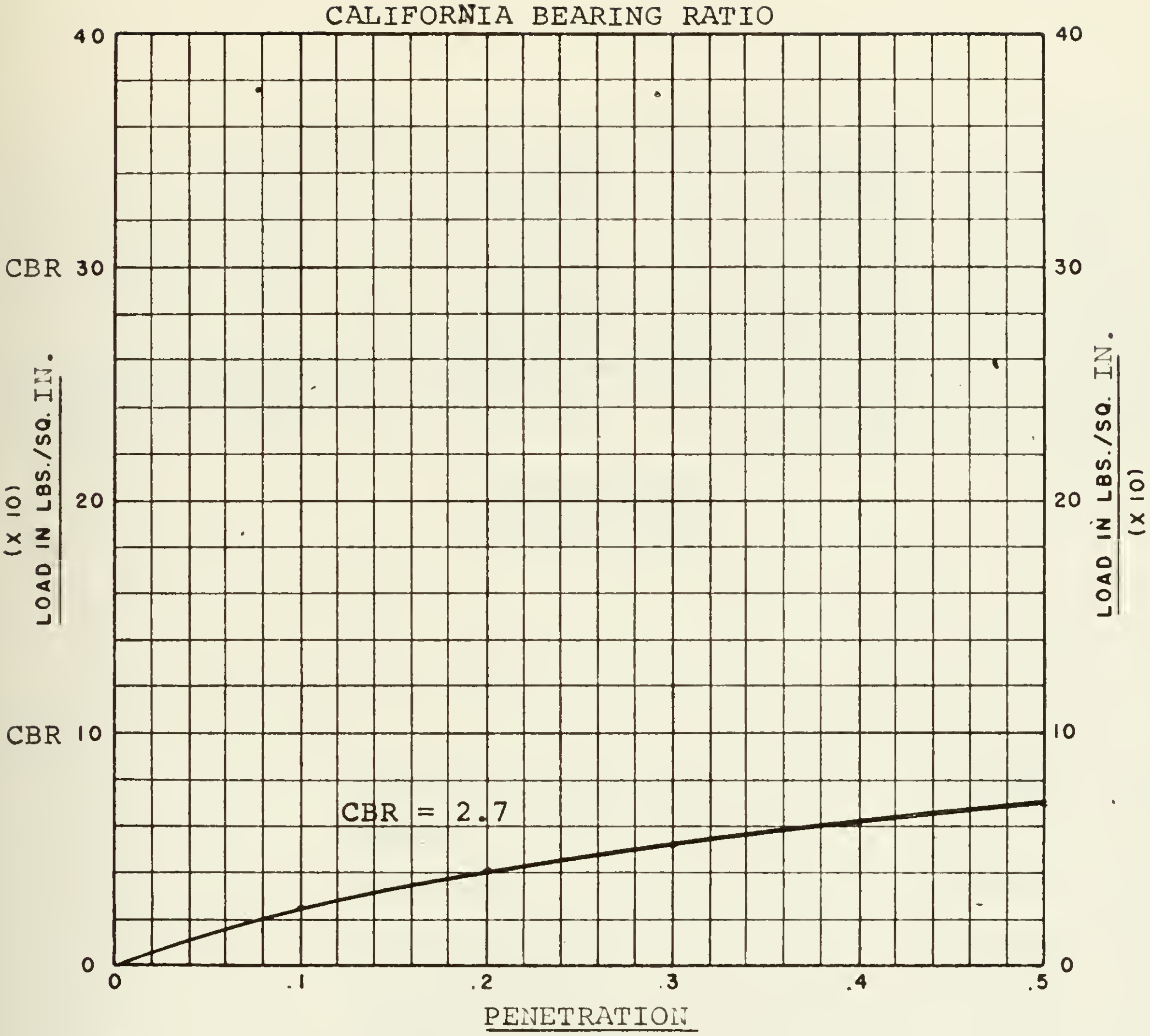
STATION	735+00
TEST PIT	#20
SOIL TYPE	Wx Shale A-6(2)
MOISTURE INITIAL	13.2%
MOISTURE FINAL	14.5%
NATURAL DRY DENSITY	118 PCF



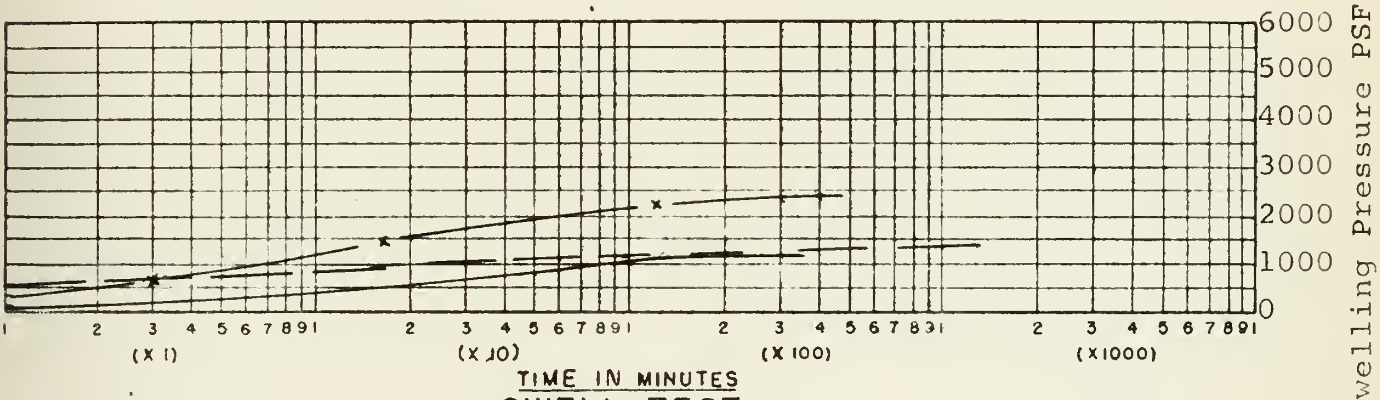
STATION 818+50 WB	
TEST PIT #13	
SOIL TYPE	Wx Green Shale A-6(8)
MOISTURE INITIAL	14.0%
MOISTURE FINAL	15.5%
NATURAL DRY DENSITY	96.5 PCF



STATION 885+00 EB
TEST PIT #18
SOIL TYPE Silt A-4(8)
MOISTURE INITIAL 12.5%
MOISTURE FINAL 16.7%
NATURAL DRY DENSITY 98 PCF

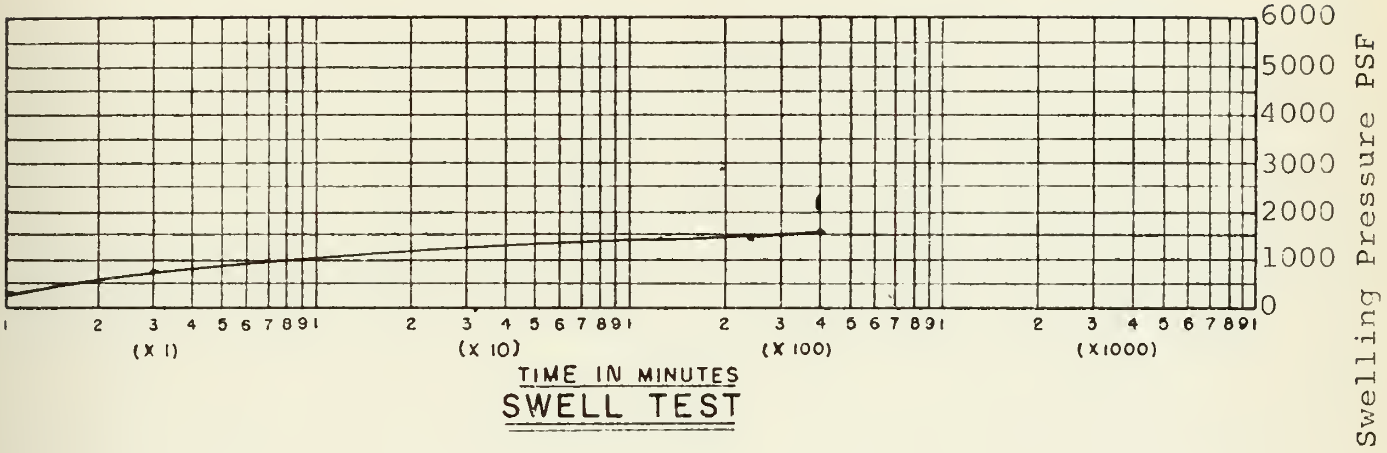


STATION	923+00 WB
TEST PIT	#16
SOIL TYPE	Wx Siltstone A-4(8)
MOISTURE INITIAL	11.7%
MOISTURE FINAL	19.8%
NATURAL DRY DENSITY	108 PCF



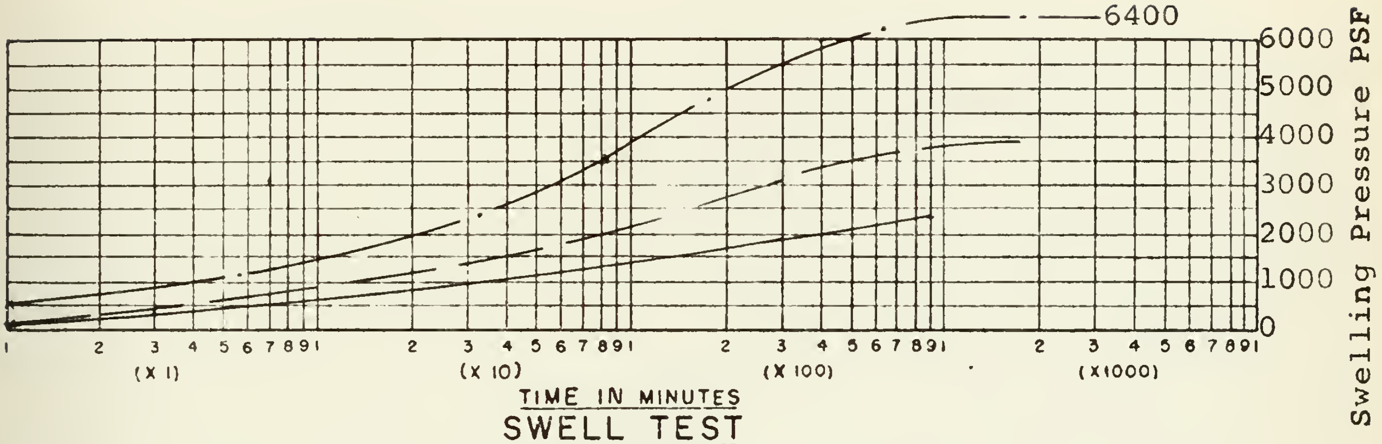
SWELL TEST

	— —	—x—	——
TEST HOLE @ Station	712	739 WB	739 WB
DEPTH	2-3'	6-7'	11-12'
SOIL TYPE	Clay	Shale	Shale
MOISTURE *INITIAL*	8.4%	11.0%	11.4%
MOISTURE *FINAL*	14.9%	15.6%	12.6%
NATURAL DRY DENSITY	115.4 PCF	122 PCF	96 PCF



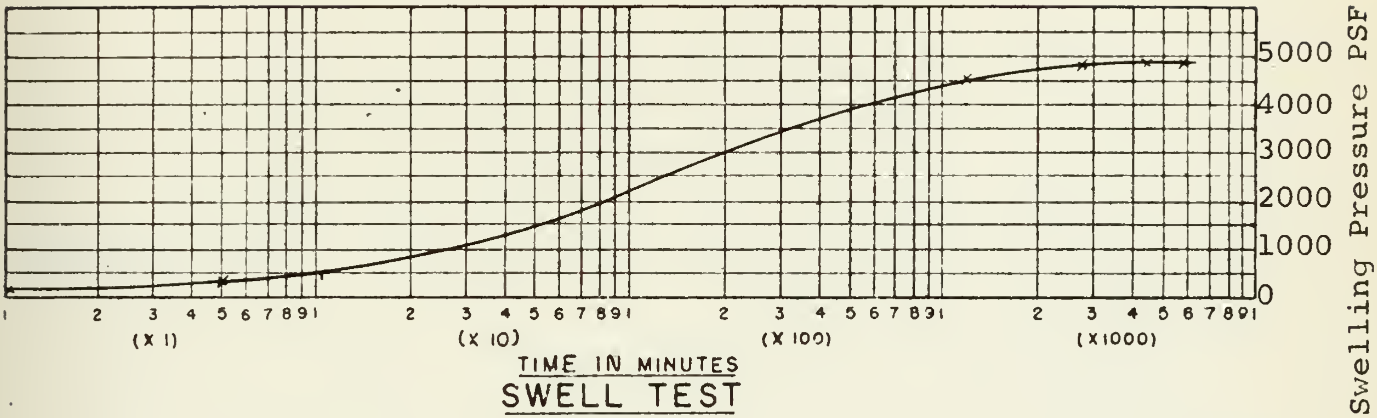
SWELL TEST

TEST HOLE @ Station 747
DEPTH 2-3'
SOIL TYPE Clay Silt
MOISTURE *INITIAL* 6.0%
MOISTURE *FINAL* 6.1%
NATURAL DRY DENSITY 110 PCF



SWELL TEST

	———	—·—	— — —
TEST HOLE @ Station	753	753	753
DEPTH	7.5-8'	16.5-17'	17.5-18'
SOIL TYPE	Green Clay Shale		
MOISTURE *INITIAL*	7.7%	7.2%	9.0%
MOISTURE *FINAL*	11.5%	9.4%	10.0%
NATURAL DRY DENSITY	131 PCF	120 PCF	118 PCF

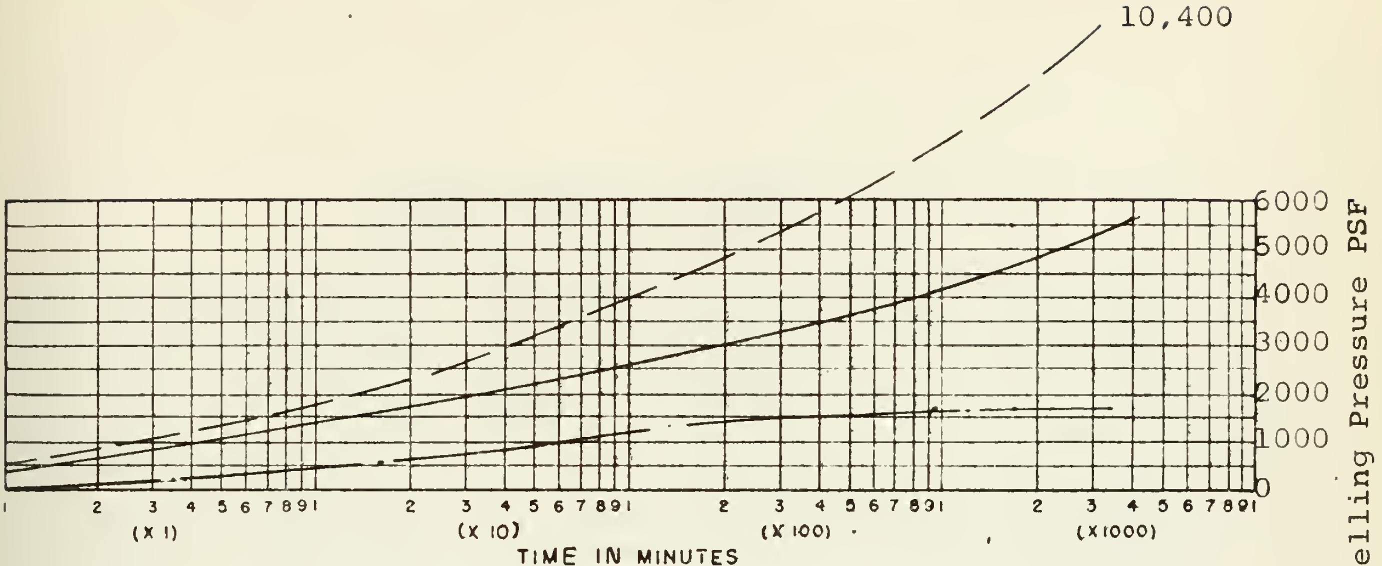


SWELL TEST

TEST HOLE .... Sta. 860+20 EB
DEPTH .... 12'- 12.5'
SOIL TYPE .... Shale, Green A-7-6 (17)
MOISTURE *INITIAL* 13.9%
MOISTURE *FINAL* 18.3%
NATURAL DRY DENSITY .... 115.0 PCF

MATERIALS & SUBSTRUCTURES, INC.

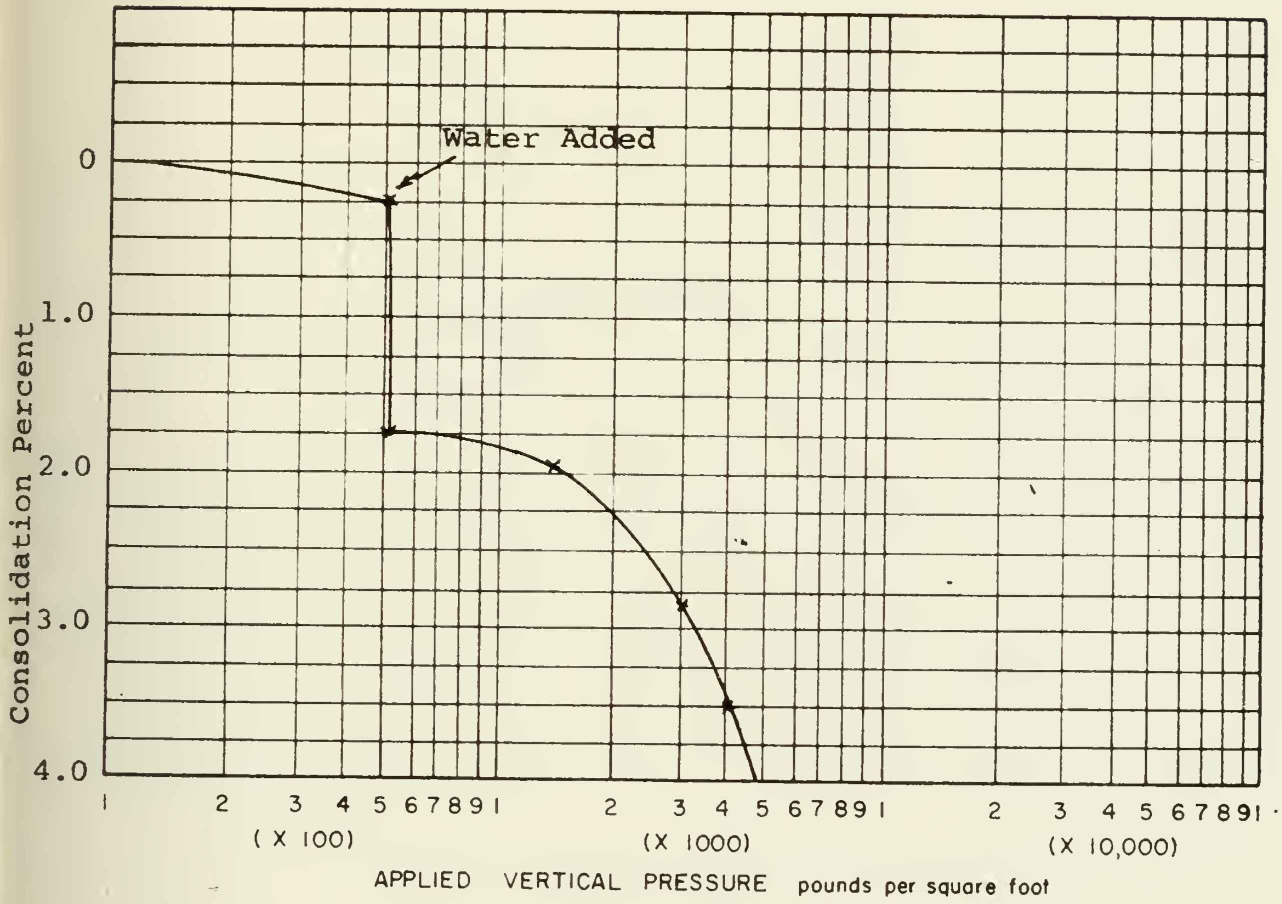
CONSULTING ENGINEERS



SWELL TEST

	— — —	———	—·—
TEST HOLE @ Station	867	867	900
DEPTH	16.5-17'	21.5-22'	2-3'
SOIL TYPE	Green Clay Shale		Clay Silt
MOISTURE *INITIAL*	13.9%	16.0%	10.9%
MOISTURE *FINAL*	18.1%	19.1%	13.9%
NATURAL DRY DENSITY	107 PCF	117 PCF	117 PCF

CONSOLIDATION TEST



TEST HOLE .... Sta. 540+20

DEPTH .... 2' - 3'

SOIL TYPE .... Silt A-6(4)

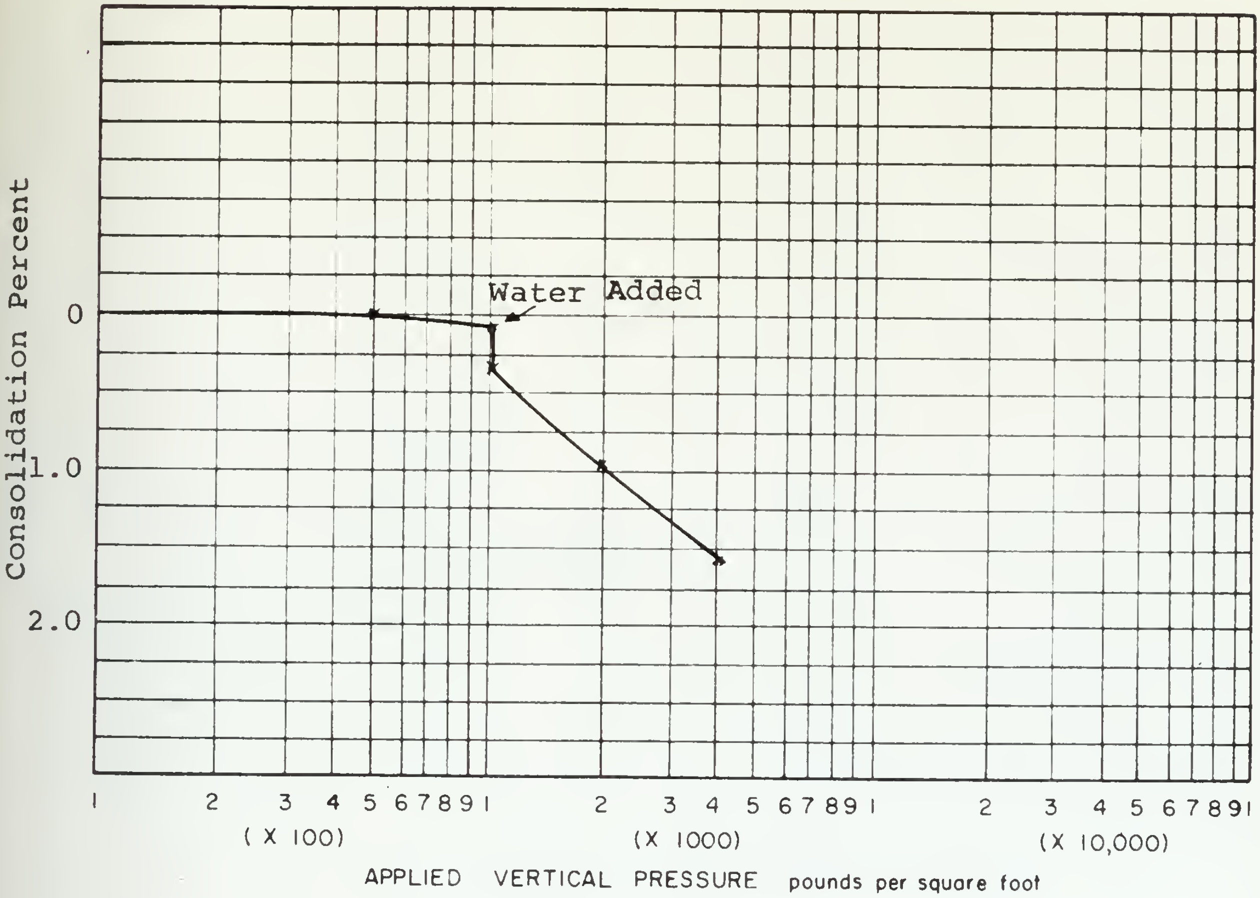
MOISTURE *INITIAL* 10.2%

MOISTURE *FINAL* 14.4%

NATURAL DRY DENSITY .... 118 PCF

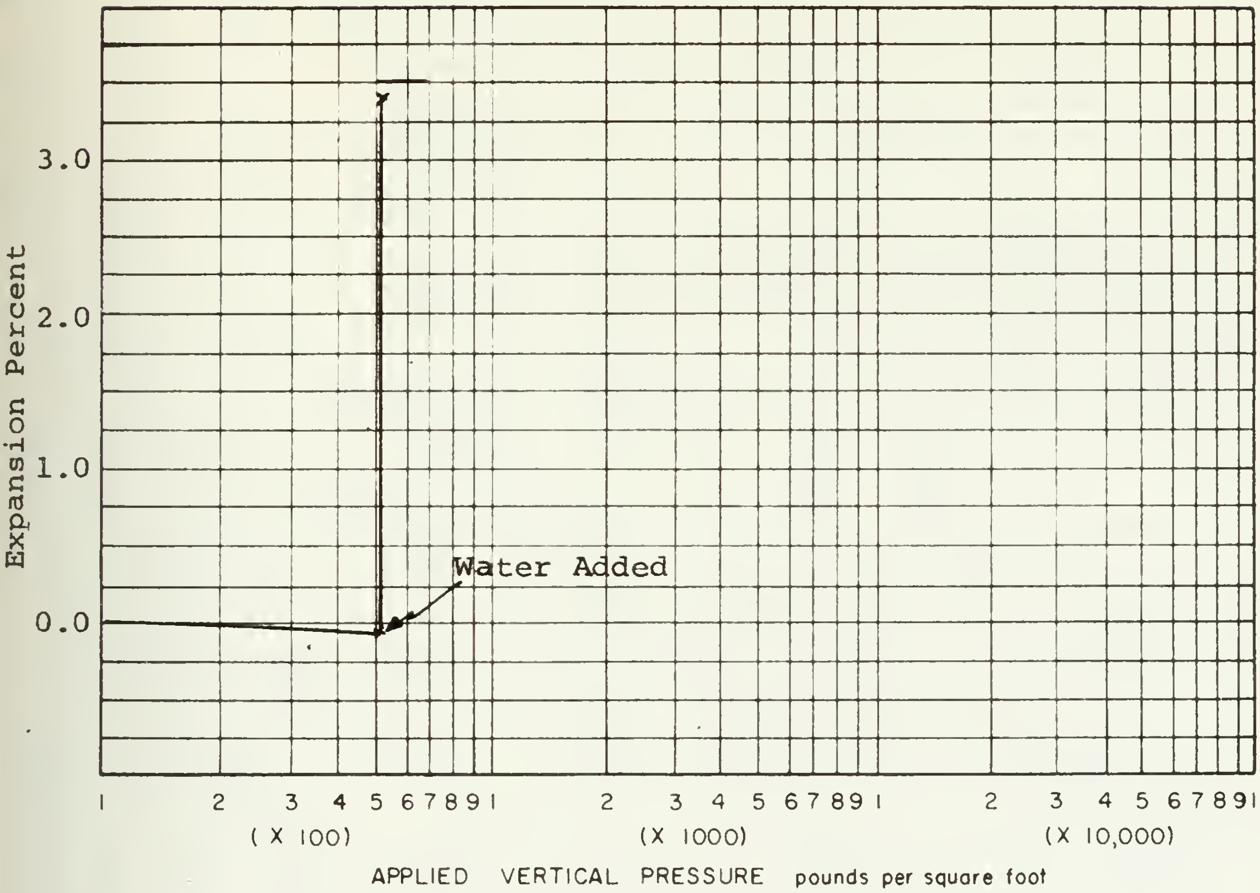
INITIAL VOID RATIO ....

CONSOLIDATION TEST



TEST HOLE .... Sta. 589+00
DEPTH .... 2.5'- 3.5'
SOIL TYPE .... Silt A-4(4)
MOISTURE *INITIAL* 11.3%
MOISTURE *FINAL* 12.5%
NATURAL DRY DENSITY .... 117.0 PCF
INITIAL VOID RATIO ....

CONSOLIDATION TEST



TEST HOLE	Sta. 860+20 EB
DEPTH	12'- 12.5'
SOIL TYPE	Shale, Green A-7-6(17)
MOISTURE *INITIAL*	13.9%
MOISTURE *FINAL*	18.6%
NATURAL DRY DENSITY	116 PCF
INITIAL VOID RATIO	

PRECONSTRUCTION SOIL SURVEY DATA, & SPECIAL RECOMMENDATIONS RELATIVE SUBGRADE & ROAD SURFACE DESIGN

DATE:

PROJ. NO. I-90-8(14)399; IIG-90-8(44)396 LENGTH 9.3 MILES,: COUNTY Stillwater

SUBMITTED BY: KEN R. WHITE COMPANY TITLE: Consultant DIV.

APPROVED: DIV. ENGR. DIST.ENGR.

UNIFORM SOIL SECTIONS		SOILS GROUP	SOILS					SOIL SAMPLE NUMBER	UNDISTURBED DENSITY	MAXIMUM DENSITY	% NATURAL MOISTURE CONTENT	OPTIMUM MOISTURE	8/67 DRAINAGE OR DEPTH TO WATER TABLE		RECOMMENDED TOTAL THICKNESS OF SURFACING	EXHIBIT NO. OF ATTACHED RECOMMENDATIONS OR UNUSUAL CONDITIONS
			CONSTANTS		GRADING											
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH									
445+76	625+00															
480+00	@ 1'	A-6(10)	30.5	14	100	98.7	87.5		108	110	7.4	15.8				
500+00	@ 2'	A-6(9)	24	13	100	99	80		109.2	110	14.7	15.8	10'			
518+32	@ 2'	A-4(8)	22	6	100	100	82		104	110	16.1	15.8				
519+56	@ 3'	A-4(1)	20	4	60	46	37			110		15.8	6.5'			
533+59	@ 3'	A-6(5)	26	11	81.5	77	60			110		15.8	16.5'			
538+85	@ 3.5'	A-4(2)	27	NP	99	94	44	16138	86.1	106.9	5.1	15.8				
540+20	@ 2'	A-6(9)	27	12	100	100	84		118	117	12.5	15.8	9.5'			
555+30	@ 3.5'	A-2-4(0)	NP	NP	97	89	27	16139	73.9	108.6	7.6	15.7	5.0'			
556+00	@ 2'	A-4(1)	NP	NP	89	85	38		101	106.9	10.0	15.7	5.0'			
565+00	@ 2'	A-4(8)	24	NP	100	100	97		90.6	106.9	23.5	15.8	4.5'			
586+00	@ 1.5'	A-4(8)	23	2	100	99	75			110		15.8				
589+00	@ 3'	A-4(4)	19	NP	100	100	56		117	117	11.3	12.5	12.0'			
613+00	@ 2'	A-6(9)	28	12	100	100	94		113.6	117	9.3	12.5				
622+35	@ 2'	A-4(8)	21	3	100	99	77		96.5	106.9	20.6	15.8	7.5			
625+00	648+00															
643+00	@ 2'	A-6(13)	37	23	100	100	98		111.2	110	14.8	15.8	5.0			
646+00	@ 6'	A-4(8)	26	7	100	100	94	16140	73.2	110	8.7	17.0				

PRECONSTRUCTION SOIL SURVEY DATA, & SPECIAL RECOMMENDATIONS RELATIVE SUBGRADE & ROAD SURFACE DESIGN

DATE:

PROJ. NO. I-90-8(14)399; IIG-90-8(44)396 LENGTH 9.3 MILES,: COUNTY Stillwater

SUBMITTED BY: KEN R. WHITE COMPANY TITLE: Consultant DIV.

APPROVED: DIV. ENGR. DIST.ENGR.

UNIFORM SOIL SECTIONS		SOILS GROUP	SOILS					SOIL SAMPLE NUMBER	UNDISTURBED DENSITY	MAXIMUM DENSITY	% NATURAL MOISTURE CONTENT	OPTIMUM MOISTURE	8/67		RECOMMENDED TOTAL THICKNESS OF SURFACING	EXHIBIT NO. OF ATTACHED RECOMMENDATIONS OR UNUSUAL CONDITIONS
			CONSTANTS		GRADING								DRAINAGE OR DEPTH TO WATER TABLE			
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH									
648+00	658+00															
658+00	680+00															
672+00	@1'	A-6(10)	28	16	100	100	95		104	118	26	14.0	Surf			
673+21	@ 4'	A-4(5)	24.5	7.4	99	94	61	16141	89.8	114.2	6.5	15.1				
677+50	@ 1'	A-4(4)	NP	NP	99	95	53			109		14.5				
680+00	725+00															
693+25	@ 2'	A-4(6)	22	7	98	97	67		100.2	110	5.0	15.8				
700+00	@ 5'	A-4(7)	20	7	100	98.6	70		118	110	8.9	15.8				
712+00	@ 2'	A-6(8)	26	12	100	99	73		115.4	117	8.4	12.5				
725+00	781+00															
730+50	@ 2'	A-4(4)	21	7	97	93	57		134.4	117	8.1	12.5				
735+00	EB @ 1'	A-6(2)	27	11	63	60	43			118		13.2				
739+00	WB @ 2'	A-4(2)	28	1	68	54	44				6.8					
739+00	WB @ 6'	A-6(6)	38	11	100	97	60		122	118	11.0	13.2				

PRECONSTRUCTION SOIL SURVEY DATA, & SPECIAL RECOMMENDATIONS RELATIVE SUBGRADE & ROAD SURFACE DESIGN

DATE: ____

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UNIFORM SOIL SECTIONS		SOILS GROUP	SOILS					SOIL SAMPLE NUMBER	UNDISTURBED DENSITY	MAXIMUM DENSITY	% NATURAL MOISTURE CONTENT	OPTIMUM MOISTURE	8/67 DRAINAGE OR DEPTH TO WATER TABLE		RECOMMENDED TOTAL THICKNESS OF SURFACING	EXHIBIT NO. OF ATTACHED RECOMMENDATIONS OR UNUSUAL CONDITIONS
			CONSTANTS		GRADING											
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH									
739+00	WB @ 11'	A-6(10)	37	14	100	100	92		96	118	11.4	13.2				
747+00	℄ @ 2'	A-4(8)	22	6	100	100	72		110	110	5.2	15.8				
747+00	℄ @ 7'	A-4(2)	19	2	80	73	47				4.0					
748+10	@ 3.5'	A-2-4(0)	22	NP	97	85	23	16142	80.8	115.2	4.3	13.2				
748+50	WB @ 1'	A-4(5)	21.5	7	93	90	62									
753+20	℄ @ 7.5	A-4(8)	31	10	100	100	92		131	118	4.2	13.2				
753+20	℄ @ 17'	A-6(11)	30	17	96	87	74		120	118	9.9	13.2				
753+20	℄ @ 18'	A-6(10)	33	15	100	99	96		118	118	9.2	13.2				
758+00	EB @ 1'	A-4(7)	28	8	84	78	70			122		11.4				
762+50	EB @ 0.5'	A-4(7)	29	9	85	83	70									
779+50	WB @ 1'	A-4(4)	26	5	63	59	56									
780+00	WB @ 1'	A-4(7)	27.5	9	84	77	68									
781+00	840+00															
818+50	WB @ 1'	A-6(8)	26	11	83	82	70			118		14.0				
821+00	WB @ 1'	A-4(8)	32	7	95	92	84									
833+40	WB @ 2'	A-2-4	NP	NP	38	29	27									
837+00	EB @ 1'	A-4(6)	21	NP	99	97	65									

STATE HIGHWAY COMMISSION

PRECONSTRUCTION SOIL SURVEY DATA, & SPECIAL RECOMMENDATIONS RELATIVE SUBGRADE & ROAD SURFACE DESIGN

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			CONSTANTS		GRADING											
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH									
840+00	874+35															
860+20	EB @ 5'	A-6(9)	24	11	97	95	88		116.5	118	5.4	13.2				
860+20	EB @ 12'	A-7-6(17)	53	37					116	118	13.9	13.2				
862+25	℄ @ 17'	A-4(8)	21	4	100	100	71		107	118	13.9	13.2				
862+25	℄ @ 22'	A-7-6(17)	52	34					117	118	16.0	13.2				
874+35	902+00															
881+45	EB @ 2'	A-4(8)	25	9	98	95	91				7.0					
885+00	EB @ 1'	A-4(8)	25	6	96	92	74			117		12.5				
893+39	WB @ 2'	A-6(9)	30	12	100	100	94				42.0					
894+53	EB @ 3'	A-4(3)	24	9	100		49									
893+35	WB @ 3'	A-6(9)	30	13	100	99	98						20.5			
899+37	@ 1.5	A-4(1)	29	5.5	99	93	42	16147	80.9	107.1	14.9	17.4				
900+00	WB @ 2'	A-4(8)	25	9					117	117	10.9		12.5			
902+00	942+65															
907+00	WB @ 2'	A-6(10)	34	17	100	100	97		102	106.9	20.0	15.7	5.0			
916+45	EB @ 3'	A-4(1)	NP	NP	100		39		95	108.6	10.6	15.7	7.0			

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			CONSTANTS		GRADING											
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH						DRAINAGE OR DEPTH TO WATER TABLE			
916+50	WB @ 3'	A-4(8)	23	6	100	100	80		95	117	10.6	12.5	19.0			
921+95	@ 3.5	A-4(1)	29	5.5	99	93	42	16147	80.9	107.1	14.9	17.4				
922+00	℄ @ 1'	A-4(3)	NP	NP	85	80	47									
923+00	WB @ 1'	A-4(8)	NP	NP	99	98	82			118		13				
934+00	℄ @ 2'	A-6(13)	38	23	100	99	97		105	106.9	10.2	15.7				
941+94	@ 3.5'	A-4(5)	34	8	100	98	62	16149	73.2	97.8	11.7	21.2				
Berry Creek Borrow																
TP 1	@ 1-6'	A-2-4	16	NP	64	47	26		→	130.5	9	8.5				
TP 4	@ 4-6'	A-2-4	18	NP	63	48	26		→	130.0	7.9	8.8				
TH 12	@ 8-9'	A-4	21	5	70	52	28									
TH 12	@ 13-14	A-4	17	1	63	52	30									